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Railroad Investigation Report RIR-24-05

Norfolk Southern Railway Derailment and Hazardous Materials Release

East Palestine, Ohio
February 3, 2023

Abstract: This report discusses the February 3, 2023, derailment and subsequent hazardous materials releases involving Norfolk Southern Railway train 32N in East Palestine, Ohio. The derailment occurred shortly after a hot bearing detector broadcast a critical alarm about a wheel bearing's temperature. The derailed equipment included 11 tank cars carrying hazardous materials. Three of these hazardous materials tank cars sustained mechanical breaches during the derailment and released flammable or combustible materials; five others released flammable gases as a result of fire exposure or deliberate breaching with explosives to perform a vent and burn procedure. The safety issues identified in this report include the failure of systems intended to identify failing wheel bearings, inadequate training of volunteer first responders, delayed transmittal of train consist information to first responders, illegibility of fire-damaged placards, use of tank cars with documented poor derailment performance, a tank car certification process that could not ensure that tank car fittings are compatible with approved commodities, misleading written guidance and information about chemical hazards, and a flawed communication and decision-making process leading up to the deliberate breach of five tank cars containing vinyl chloride monomer. New recommendations are made to the Secretary of Transportation, the Federal Railroad Administration, the Pipeline and Hazardous Materials Safety Administration, the state of Ohio, the Columbiana County Emergency Management Agency, the Association of American Railroads, the International Association of Fire Chiefs, the International Association of Fire Fighters, the National Volunteer Fire Council, The Chlorine Institute, the American Chemistry Council, Norfolk Southern Railway, and Oxy Vinyls, LP. One recommendation is reiterated to the Class I railroads. One recommendation to the Secretary of Transportation, one recommendation to the Pipeline and Hazardous Materials Safety Administration, and two recommendations to the Federal Railroad Administration are classified.

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Acronyms and Abbreviations

Abbreviation	Name
AAR	Association of American Railroads
ABD	acoustic bearing detector
ATC	advanced train control
BLEVE	boiling liquid expanding vapor explosion
BOV	bottom outlet valve
CCEMA	Columbiana County Emergency Management Agency
<i>CFR</i>	<i>Code of Federal Regulations</i>
CHLOREP	Chlorine Emergency Plan
CISA	Cybersecurity and Infrastructure Security Agency
CLM	car location messaging
EMS	emergency medical services
EPFD	East Palestine Fire Department
EPPD	East Palestine Police Department
ERG	Emergency Response Guidebook
ERI	Emergency Response Information
ESI	Explosive Service International
FAST Act	Fixing America's Surface Transportation Act
Fed. Reg.	<i>Federal Register</i>
FEMA	Federal Emergency Management Agency

Abbreviation	Name
FRA	Federal Railroad Administration
HBD	hot bearing detector, also called a hotbox detector
HHFT	high-hazard flammable train
IAFC	International Association of Fire Chiefs
IAFF	International Association of Fire Fighters
MP	milepost
NECP	National Emergency Communications Plan
NFPA	National Fire Protection Association
NPRM	Notice of Proposed Rulemaking
NIMS	National Incident Management System
NS	Norfolk Southern Railway
NTSB	National Transportation Safety Board
NVFC	National Volunteer Fire Council
Ohio EMS	Ohio Division of Emergency Medical Services
PHMSA	Pipeline and Hazardous Materials Safety Administration
PL	Public Law
PRD	pressure relief device
PSAP	Public Safety Answering Point
psig	pounds per square inch (gauge)
PTC	positive train control

Abbreviation	Name
PVC	polyvinyl chloride
SDS	safety data sheet
SPSI	Specialized Professional Services, Inc
SRS	Specialized Response Solutions
TRRA	Terminal Railroad Association of St. Louis
TSB	Transportation Safety Board of Canada
USDOT	United States Department of Transportation
VCM	vinyl chloride monomer
WENS	Wireless Emergency Notification System

Executive Summary

What Happened

On February 3, 2023, about 8:54 p.m., eastbound Norfolk Southern Railway (NS) train 32N derailed 38 mixed freight railcars at milepost 49.5 on the NS Fort Wayne Line of the Keystone Division in East Palestine, Ohio. Three tank cars carrying flammable and combustible hazardous materials were mechanically breached during the derailment. A fire ignited during the derailment and grew to involve lading released from these three mechanically breached tank cars, additional derailed tank cars carrying both hazardous and non-hazardous materials, and freight cars. Emergency responders established a 1-mile evacuation zone that affected about 2,000 residents. The derailed equipment included five hazardous materials tank cars carrying vinyl chloride monomer (VCM), a compressed liquified flammable gas offered for shipment as "UN1086 vinyl chloride, stabilized, 2.1." The five VCM tank cars were not mechanically breached during the derailment, but over the next day, four of these tank cars were exposed to fires and released material from pressure relief devices. These releases ceased on the afternoon of February 4. Acting on information provided by NS and its contractors that a dangerous chemical reaction was occurring within a VCM tank car, the incident commander managing the response chose to expand the evacuation zone and perform a vent and burn (a deliberate breach of a tank car) on all five derailed VCM tank cars. The incident commander was not aware of dissenting opinions the VCM shipper had provided to NS and its contractors. A contractor hired by NS breached the VCM tank cars at 4:37 p.m. on February 6, releasing and igniting their lading. No injuries were reported during the derailment or emergency response.

What We Found

The derailment occurred because a bearing on a hopper car overheated and caused an axle to separate. There was not enough evidence to determine whether a mechanical inspection conducted before the derailment failed to identify signs of bearing failure; the bearing may not have been showing visible problems at the time of the inspection.

A hot bearing detector traversed by train 32N detected an elevated temperature on the overheating bearing, but the low-priority alert it transmitted to railroad personnel did not reflect the true condition of the failing bearing. Because of design constraints, hot bearing detectors are likely to indicate misleadingly low bearing temperatures. This limit on detector performance, combined with NS's

standard operating procedures and the spacing between detectors, meant that the train's crew did not have adequate warning to stop the train before the derailment.

Research will be necessary to determine whether changes to wayside bearing defect detection systems—such as lower alert and alarm thresholds—would produce a significant safety improvement. Research is also necessary to determine what operational responses to bearing alerts and alarms are sufficient to prevent derailments.

The state of Ohio's laws regarding volunteer firefighter training were not sufficient to support a safe emergency response to the derailment. Further, the emergency response lacked efficient coordination because the responding agencies did not have common radio channels. Also hampering efforts was the illegible railcar placards after fire exposure. Delays in NS transmitting train consist information to emergency responders also increased responders' and the public's exposure to postderailment hazards.

The postderailment fires likely began because of hazardous materials released from a punctured DOT-111 tank car. The subsequent release of VCM from mechanically intact DOT-105 tank cars likely would not have occurred if the DOT-111 tank cars in the consist had survived the derailment. The presence of hazardous materials DOT-111 tank cars in a train can increase the risk of more resilient tank cars releasing hazardous materials following a derailment; the definition of key train does not account for this. Voluntary phase out of the remaining DOT-111 tank cars in hazardous materials service is technically possible but unlikely because of economic and business disincentives.

The VCM in the derailed DOT-105 tank cars remained in a stabilized environment (that is, was unable to undergo polymerization, a potentially dangerous chemical reaction) until those tank cars were deliberately breached with explosives (the vent and burn procedure). On-scene temperature trends did not indicate that a polymerization reaction was occurring and postaccident examinations confirmed this. The vent and burn procedure was not necessary to prevent a polymerization-induced explosion. One source of information about polymerization consulted by NS and its contractors, The Chlorine Institute's Pamphlet 171, included misleading information about signs of polymerization. NS and its contractors continued to describe polymerization as an imminent threat when expert opinions and available evidence should have led them to reconsider their course of action. NS compromised the integrity of the decision to vent and burn the tank cars by not communicating expertise and dissenting opinions to the incident commander making the final decision. This failure to communicate completely and accurately with the incident

commander was unjustified. The high local and environmental impacts of a vent and burn decision demonstrate the need for federal guidance about when to conduct a vent and burn.

Lastly, inward- and outward-facing recorders can provide the opportunity for railroads to verify train crew actions and for investigators to improve the quality of investigations; without a requirement, we have missed an opportunity to record important safety data.

The National Transportation Safety Board determines that the probable cause of the derailment involving Norfolk Southern Railway train 32N was the failure of the L1 bearing on the 23rd railcar in the consist that overheated and caused the axle to separate, derailing the train and leading to a postderailment fire that likely began with the release of a Class 3 flammable liquid from a DOT-111 tank car that was punctured during the derailment. Contributing to the postderailment fire and the severity of the hazardous materials release was the continued use of DOT-111 tank cars in hazardous materials service. Also contributing to the severity of the hazardous materials release were (1) the failure of Norfolk Southern Railway and its contractors to communicate relevant expertise and dissenting opinions to the incident commander and (2) the inaccurate representation by Norfolk Southern Railway and its contractors that the tank cars were at risk of catastrophic failure from a polymerization reaction, which created unwarranted urgency and led to the unnecessary decision to vent and burn five derailed vinyl chloride monomer tank cars to prevent a polymerization-induced tank car rupture. Contributing to the exposure of emergency responders and the public to postderailment hazards were (1) Norfolk Southern Railway's delay in transmitting the train consist information to emergency responders and (2) the state of Ohio's insufficient training requirements for volunteer firefighters.

What We Recommended

As a result of this investigation, we issued 34 new recommendations, reiterated 1 previously issued recommendation, and classified 4 recommendations.

We asked the Federal Railroad Administration (FRA) to conduct research on bearing defect detection systems, and recommended that the FRA use the results to establish regulations on related subjects:

- Railroads' use of bearing defect detection systems, including thresholds for alerts and alarms and distances between wayside detectors;

- Railroads' operational responses to bearing alerts and alarms; and
- Installation, inspection, and maintenance of wayside bearing defect detection systems.

We recommended that the Association of American Railroads develop a database of bearing failure and replacement data to help railroads, regulators, and investigators identify and address bearing failure risk factors.

We issued a recommendation to the state of Ohio to amend its statute limiting volunteer firefighter training and bring its training requirements in line with a widely accepted standard. To expand the reach of lessons learned at East Palestine, we recommended that the International Association of Fire Chiefs, the International Association of Fire Fighters, and National Volunteer Fire Council inform their members of the derailment and fire and encourage them to adopt training that meets a widely accepted standard. We also recommended that the National Volunteer Fire Council identify barriers to volunteer firefighter training and actions to address them.

To improve local preparedness, we recommended that the Columbiana County Emergency Management Agency develop a policy to immediately provide train consists to emergency responders and update its emergency plans to incorporate lessons learned from the East Palestine derailment.

We classified Closed–Acceptable Action a recommendation to the Pipeline and Hazardous Materials Administration (PHMSA) that it require railroads to immediately provide emergency responders with train consist information (R-07-4, Open–Unacceptable Response). We also recommended that NS review and revise its practices to ensure immediate communication of the consist to first responders. We made a new recommendation that PHMSA require that placards used to identify hazardous materials be able to survive accidents and fires.

We issued additional new recommendations to PHMSA expanding and accelerating the current phase out of DOT-111 tank cars from hazardous materials service and expanding the definition of high-hazard flammable trains to include a wider variety of hazardous materials and account for variations in how well different tank car specifications survive derailments. We made a related recommendation to the Association of American Railroads to account for the risk posed by certain tank cars in its definition of key train. We also recommended that the Association of American Railroads take steps to require manufacturers of tank car service equipment to demonstrate that their products are compatible with a tank car's intended lading

and that the FRA monitor the Association of American Railroads' progress to ensure they address weaknesses in their approval process.

Regarding the vent and burn decision, we recommended that The Chlorine Institute review and revise its pamphlet on VCM to ensure that it is accurate and suited to supporting emergency responses, and that it change its Chlorine Emergency Plan program to make sure specialized emergency response contractors can appropriately respond to chemical hazards during a VCM incident; that Oxy Vinyls update its safety data sheet for VCM to ensure that it is accurate and develop a policy to ensure that its expertise is communicated to the full incident command; that the American Chemistry Council and The Chlorine Institute make their members aware of the events at East Palestine and emphasize the importance of shippers communicating their expertise to the full incident command; that NS establish a policy of communicating all expert opinions to the full incident command, share information collected by its emergency response contractors with entities that provide hazardous materials guidance, and update its submissions to the PHMSA incident database; that the FRA disseminate current and updated versions of its existing study on the vent and burn method to help guide incident commands in the future; and that PHMSA spread awareness of the FRA's most current guidance by referencing it in the next edition of the Emergency Response Guidebook. We made an additional recommendation to the International Association of Fire Chiefs, the International Association of Fire Fighters, and National Volunteer Fire Council to encourage the distribution of federal guidance about the vent and burn method.

We also classified Closed–Superseded recommendations to the Secretary of Transportation and the FRA regarding the installation and use of inward- and outward-facing audio and image recorders on locomotives (R-10-1, and R-10-2 to the FRA were Open–Unacceptable Response; R-19-7 to the Secretary of Transportation was Open–Await Response). We recommended that the FRA and Secretary of Transportation take the actions described in the closed recommendations, obtaining legislative authority to act if necessary.

We reiterated one recommendation to the Class I railroads regarding installation and use of audio and image recorders (R-13-26, Open–Acceptable Response).

1 Factual Information

1.1 Derailment Description

On February 3, 2023, about 8:54 p.m., eastbound Norfolk Southern Railway (NS) train 32N derailed 38 mixed freight railcars at milepost (MP) 49.5 on main track 1 of the NS Fort Wayne Line of the Keystone Division in East Palestine, Ohio.¹ The derailed equipment included 11 tank cars carrying hazardous materials. Three of these tank cars, carrying flammable and combustible hazardous materials, were mechanically breached during the derailment and released lading.² A fire ignited during the derailment and grew to involve 35 railcars: the 3 mechanically breached hazardous materials tank cars, 20 additional derailed tank and freight cars carrying both hazardous and non-hazardous materials, and 12 non-derailed freight cars. (See figure 1.) Emergency responders established a 1-mile evacuation zone that affected about 2,000 residents. Five of the derailed hazardous materials tank cars that were not mechanically breached in the derailment were carrying vinyl chloride monomer (VCM) offered for shipment as “UN1086 vinyl chloride, stabilized, 2.1.”³ Over the next day, these tank cars were exposed to fires and released material from pressure relief devices (PRDs).⁴ These releases ceased on the afternoon of February 4 after the fires were mostly extinguished. Acting on information provided by NS and its contractors that a dangerous chemical reaction was occurring within a VCM tank car, the incident commander managing the response chose to expand the evacuation zone and perform a vent and burn (a deliberate breach of a tank car) on all five derailed VCM tank cars. The incident commander was not aware of dissenting opinions the VCM shipper had provided to NS and its contractors regarding this chemical reaction. A contractor hired by NS breached these VCM tank cars at 4:37 p.m. on February 6,

¹ (a) All times in this report are local time. (b) Visit [nts.gov](https://www.nts.gov) to find additional information in the [public docket](#) for this National Transportation Safety Board (NTSB) accident investigation (case number RRD23MR005). Further information is also available in the [public docket](#) for the NTSB Investigative Hearing held on June 22–23, 2023. Use the [CAROL Query](#) to search safety recommendations and investigations.

² *Lading* is synonymous with cargo. In this report, lading refers to materials transported in tank cars. Refer to Title 49 *Code of Federal Regulations (CFR)* Part 174 for more detailed regulatory uses of lading and related terms such as *bill of lading*.

³ This shipping name indicates a flammable gas. A detailed explanation of the shipping name is provided in section 1.8, and the properties of VCM are discussed in section 1.8.1.

⁴ *PRDs* are spring-loaded valves designed to release material if the pressure in a tank rises above a design threshold.

releasing and igniting their lading. No injuries were reported during the derailment or emergency response. NS estimated the damage to equipment to be about \$3.4 million.⁵



Figure 1. Overhead view of derailment and early fire. (Courtesy of Eric's Train Yard.)

1.1.1 Prederailment Train Movements

Train 32N operated as an NS train from Madison, Illinois, until its derailment in East Palestine, Ohio. Its route is illustrated in figure 2.

⁵ The NTSB does not directly assess environmental impacts. Questions about environmental impacts should be directed to the Environmental Protection Agency.



Figure 2. Train 32N's route.

NS received train 32N in interchange in the Terminal Railroad Association of St. Louis (TRRA) yard in Madison, Illinois, on February 1, 2023.⁶ Qualified TRRA mechanical inspectors performed a brake test and mechanical inspection of the entire consist as required by Title 49 *Code of Federal Regulations (CFR)* Parts 232 and 215.⁷ At the time of the inspection, the train consisted of 3 locomotives at the head end and 163 mixed freight railcars, including railcar GPLX75465 (hereafter the hopper car). The inspection did not result in any defect reports, and the train was approved for departure.

The train departed the TRRA yard with an NS crew at 10:14 p.m. on February 1, eastbound and destined for Conway Yard in Conway, Pennsylvania, with several intermediate stops. It arrived in an NS railyard in Decatur, Illinois, at 6:10 a.m. on February 2. A yard crew removed 55 railcars from the consist, added 40 railcars to the rear of the train, and repositioned one locomotive at line 112 as a distributed power

⁶ (a) A train or railcar is *received in interchange* when one railroad turns it over to another. In this case, NS received train 32N from TRRA. (b) TRRA is a Class III switching and terminal railroad co-owned by several Class I railroads or their parent companies, including the Norfolk Southern Corporation.

⁷ (a) A *qualified mechanical inspector* is defined in 49 CFR 229.5 as a person who has received instruction and training that includes hands-on experience in troubleshooting, inspection, testing, maintenance, or repair of locomotive equipment and whose primary responsibility is related to those functions. (b) Title 49 CFR Part 232 requires tests of air brake systems when railcars are added to a train; Part 215 requires pre-departure inspections of each railcar being placed in a train.

locomotive.⁸ Qualified NS mechanical inspectors conducted a brake test and mechanical inspection on the 40 new railcars, as required by 49 *CFR* Parts 232 and 215, before adding them to train 32N.

Train 32N departed the Decatur railyard at 4:15 p.m. on February 2. Upon departure, train 32N consisted of 3 locomotives and 149 mixed freight cars (including 9 empty railcars distributed throughout the consist); the train weighed 17,977 tons and was 9,309 feet long. The train's consist remained unchanged throughout the train's subsequent movements.

The train arrived in Toledo, Ohio, about 1:00 p.m. on February 3, where the accident crew—an engineer, a conductor, and a conductor trainee—went on duty at 1:15 p.m.⁹ The accident crew conducted a briefing with the previous crew and tested the train's brakes before departing.¹⁰ The train departed Toledo, Ohio, at 2:15 p.m., beginning the last leg of its trip before the derailment.

During this leg, train 32N encountered three hot bearing detectors (HBDs) as shown in figure 3 and described below.¹¹ It fully traversed the first two and derailed while passing over the third.

⁸ (a) A *line number* indicates the position of a piece of equipment in a train consist. Higher numbers are nearer the rear of the consist. Line numbers count locomotives while other common ways of describing railcar positions do not. As a result, line numbers differ from other descriptions of railcar positions; the 23rd railcar in train 32N was at line number 25, for example, because the train had 2 head-end locomotives. (b) *Distributed power locomotives* are used to manage in-train forces and improve the handling of long or heavy trains.

⁹ The engineer had been hired by NS as a conductor in 1996 and had about 24 years of experience as an engineer. The conductor had been hired by NS in April 2022 and been promoted to conductor in July 2022. The conductor trainee had been hired by NS in October 2022.

¹⁰ This test involved applying and releasing pressure through the air brake system to confirm continuity, or that the air brakes would apply and release on the last railcar in the consist.

¹¹ An *HBD* is a device located along the track, or wayside, designed to detect overheated bearings by using a pair of upward-facing infrared cameras to measure bearing temperatures relative to ambient (background) temperatures. Overheated bearings occur when inadequate lubrication, component misalignment, or mechanical damage increase bearing friction. The rail industry calls this phenomenon a "hot box" and sometimes refers to HBDs as "hot box detectors."

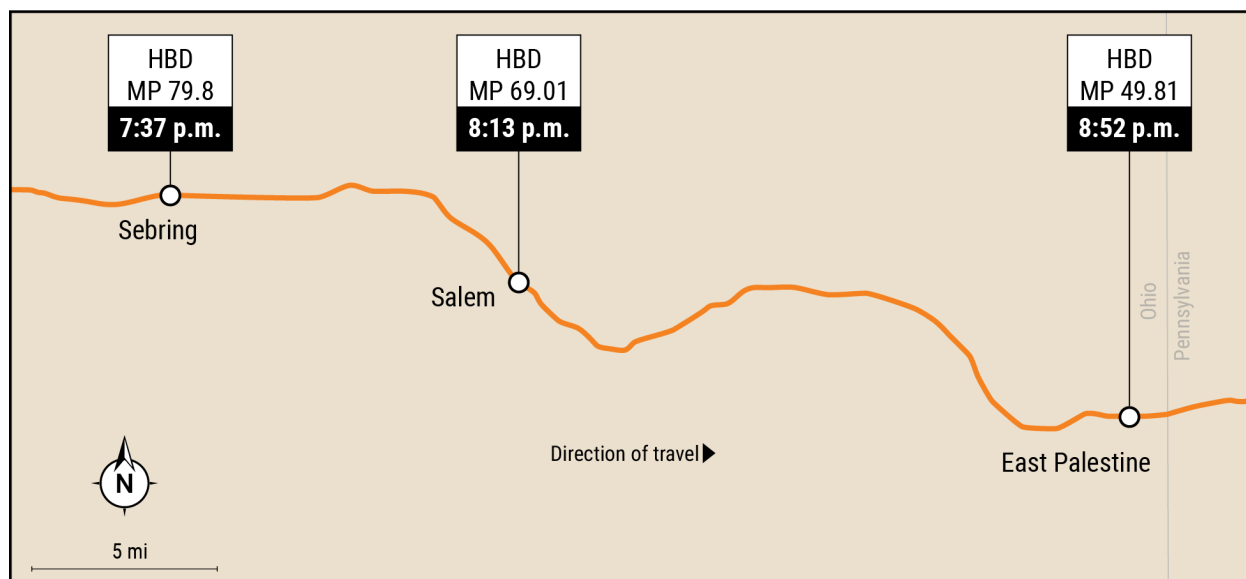


Figure 3. Map of final three HBDs encountered before derailment.

At 7:37 p.m., train 32N passed over an HBD at MP 79.8 in Sebring, Ohio. The HBD recorded a temperature 38°F above ambient on the right-side bearing of the 101st wheelset to pass the detector.¹² This corresponded to the left-side bearing on the first axle (the L1 bearing of wheelset #1) of the 23rd railcar, GPLX75465, the hopper car.¹³ (See figure 4.) The HBD recorded a temperature 20°F above ambient for the right-side bearing on the same axle (the R1 bearing). The bearing temperatures did not result in any alert or alarm.

¹² The ambient temperature was measured by a thermometer at the nearby signal bungalow; this method of determining ambient temperature is typical for HBDs.

¹³ In the freight rail industry, railcar axles are consistently numbered from the end of the railcar with the brake wheel (the B end). When the B end faces the direction of travel, the railcar's left-side wheels and bearings will be on the right side of the train. For hopper car GPLX75465, the L1 bearing was on the right side of the train in the direction of travel, or above the south rail.

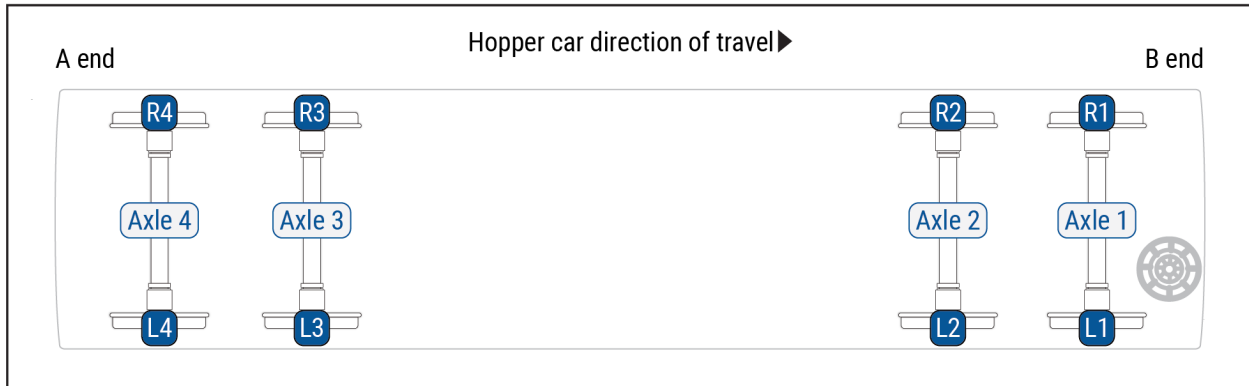


Figure 4. Diagram of hopper car wheelset and bearing positions.

Between 8:11 p.m. and 8:14 p.m., train 32N passed four surveillance cameras in Salem, Ohio, that recorded images of the train. The images showed a fire on wheelset #1 of the hopper car. (See figure 5 for an image from a surveillance camera positioned on South Lincoln Avenue.) The images did not show signs of fire on other railcars.

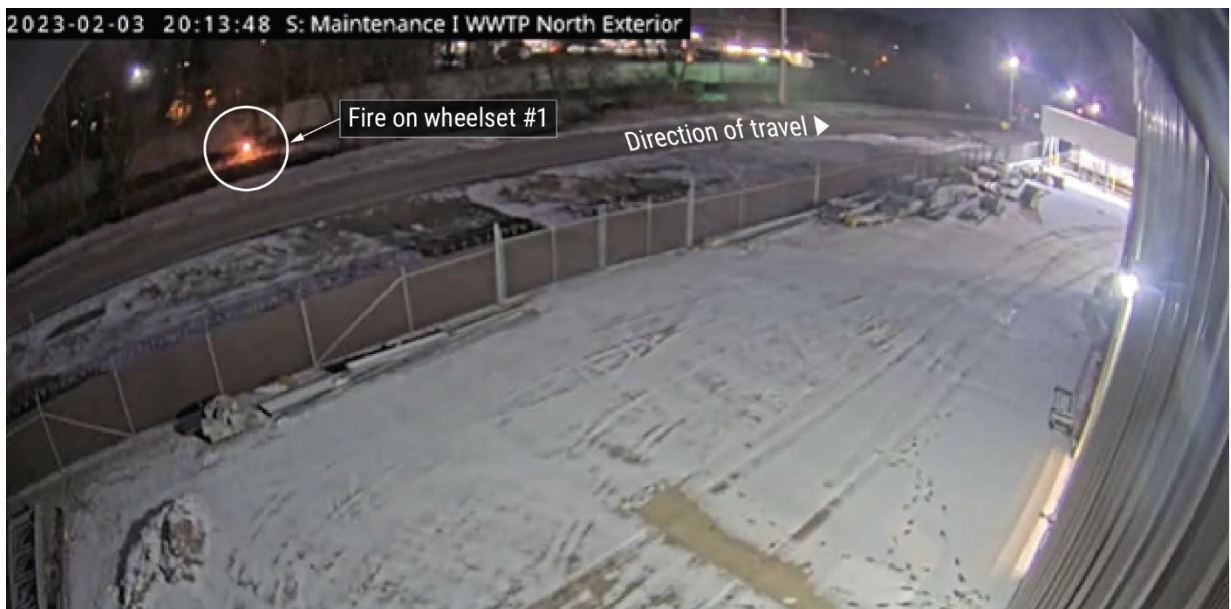


Figure 5. Fire on wheelset #1 of the hopper car passing through Salem, Ohio.

At 8:13 p.m., train 32N passed over the HBD in Salem, Ohio, (MP 69.01) near the surveillance cameras that recorded fire on the hopper car. The HBD recorded a temperature 103°F above ambient on the L1 bearing of the hopper car—a

temperature exceeding NS's 90°F above-ambient threshold for a non-critical alert.¹⁴ The R1 bearing was 20°F above ambient. The HBD transmitted a non-critical alert to the advanced train control (ATC) desk about the temperature of the L1 bearing but, as designed, did not broadcast an alarm to the train's crew. The HBD did not transmit an alert about any other bearings. Train 32N's prederailment movements are summarized in figure 2 above and in table 1.

Table 1. Timeline of prederailment events.

Date	Time	Location	Event
2/1/2023	8:30 p.m.	Madison, Illinois	Train 32N is mechanically inspected in the TRRA yard by qualified mechanical inspectors.
2/1/2023	10:14 p.m.	Madison, Illinois	Train 32N departs the TRRA yard with an NS crew.
2/2/2023	12:31 p.m.	Decatur, Illinois	NS crews remove 55 railcars from the consist and add 40 pre-inspected railcars.
2/2/2023	4:15 p.m.	Decatur, Illinois	Train 32N departs the NS yard with an NS crew.
2/3/2023	1:15 p.m.	Toledo, Ohio	The accident crew goes on duty and conducts a briefing with train 32N's previous crew.
2/3/2023	2:15 p.m.	Toledo, Ohio	Train 32N departs the NS yard with the accident crew.
2/3/2023	7:37 p.m.	Sebring, Ohio	Train 32N traverses an HBD; no axles trigger alerts or alarms.
2/3/2023	8:11-14 p.m.	Salem, Ohio	Surveillance cameras capture images of fire near the L1 bearing of the hopper car.
2/3/2023	8:13 p.m.	Salem, Ohio	Train 32N traverses an HBD; the L1 bearing of the hopper car triggers a non-critical alert.

1.1.2 Derailment and Initial Emergency Response

About 8:52 p.m. on February 3, 2023, train 32N began to traverse an HBD at MP 49.81 in East Palestine, Ohio. Locomotive event recorder data showed the train was traveling about 43 mph. The maximum authorized speed in the area was 50 mph. Less than a minute later, this HBD recorded a temperature 253°F above ambient on

¹⁴ Under NS procedures, a *non-critical alert* requires the ATC Wayside Help Desk analyst to monitor a bearing's temperature but does not require an immediate stop-and-inspect. Unlike alarms, alerts are not automatically broadcast to a train's crew. For more details on hot bearing alerts and alarms, see section 1.5.1.

the L1 bearing of the hopper car; the R1 bearing was still 20°F above ambient.¹⁵ The HBD immediately transmitted a critical alarm. The alarm was received by the lead locomotive radio and broadcast over the in-cab speakers: “Critical alarm, critical alarm, critical alarm. Norfolk Southern milepost 49.8, track 1 hotbox, axle 101, south rail.”¹⁶

Under NS operating rules, a critical alarm requires a train’s crew to immediately stop the train and inspect the wheelset that triggered the alarm. According to event recorder data, the engineer began to slow the train using dynamic braking before 8:54 p.m.¹⁷ Shortly afterward, when the head end of the train was near MP 49.5 and the consist was still passing over the HBD, the train experienced a train-line-initiated emergency braking application.¹⁸ The head-end locomotives then traveled about 1,160 feet before coming to a stop 38 seconds later. The crew radioed to NS dispatch that it had experienced an emergency. The NS Cleveland East dispatcher confirmed the emergency at 8:56 p.m. and began coordinating train movements in the area to prevent other trains from colliding with train 32N.

The East Palestine Police Department (EPPD) public safety answering point (PSAP) received the first 911 call reporting a derailment, explosion, and fire at 8:56:49 p.m.¹⁹ Additional 911 calls followed shortly afterward. East Palestine dispatch radioed an alarm to the East Palestine Fire Department (EPFD) at 8:58 p.m., requesting all available fire and emergency medical services (EMS) units to respond to a train derailment and fire. Dispatch records from East Palestine and Beaver County (a

¹⁵ A reading of 253°F above ambient is the maximum reading for the type of HBD installed at MP 49.81; the actual temperature may have been higher.

¹⁶ The alarm was captured by in-cab audio recording devices. The subject is outlined in section 1.3.

¹⁷ *Dynamic braking* uses locomotives’ traction motors to slow a train.

¹⁸ An *emergency braking application* uses the maximum braking force available and is designed to stop a train as quickly as possible. An engineer can initiate one, usually as a last resort to avoid a collision. An emergency braking application can also be initiated automatically. In most trains, including train 32N, the air brakes are activated by reducing the pressure in the *train line* (or *brake pipe*) that runs the length of the consist. If the air hoses joining railcars together become disconnected, as may occur during a derailment, the pressure in the train line falls, automatically applying the emergency brakes.

¹⁹ The Communications Division of the EPPD operated the PSAP, or 911 center, for East Palestine. It also operated the emergency services dispatching facility (dispatch), which was responsible for receiving and dispatching radio calls for police, fire, and emergency medical services (EMS) for East Palestine and nearby civil municipalities.

nearby county in Pennsylvania) indicate that 48 agencies were involved in the emergency response, including fire departments from neighboring communities and hazardous materials teams from East Liverpool, Ohio, and Beaver County, Pennsylvania. When interviewed by the National Transportation Safety Board (NTSB), personnel from EPPD and EPFD said they arrived on the scene about 9:00 p.m. and found derailment equipment and several fires, including a pool fire along the length of the derailment pileup.²⁰ The EPFD deputy fire chief assumed the role of incident commander and placed a phone call to the EPFD fire chief, who was on leave. The deputy fire chief established a command post about 400 feet from the east end of the derailment pileup at a business property owned by Leake Oil, a company that sells petroleum products such as heating oil and gasoline. (See figure 6.) The property was being used to store petroleum products at the time of the derailment.



Figure 6. Map of derailment site and command post.

Shortly after arriving on the scene, on the deputy fire chief's instructions, the EPFD began spraying water over the burning railcars. When interviewed by the NTSB,

²⁰ (a) Unless otherwise specified, interviews referenced in this report took place after the conclusion of the emergency response. (b) The term *pool fire* appears in federal regulations, such as 49 CFR Part 179 Appendix B, but it is not precisely defined. Generally, a pool fire is a fire fed by released material capable of engulfing a tank car.

the deputy fire chief said that he promptly found this tactic insufficient to suppress the fire, and that “the fire became much larger than I personally have ever seen.”

At 9:04 p.m., East Palestine dispatch called the NS dispatch center in Atlanta, Georgia, to request train consist information. The individual who answered the phone said they would call back. The NTSB has no evidence that NS returned the call to East Palestine dispatch with the requested train consist information.

During the initial stages of the emergency response, while the conductor of train 32N was preparing to walk back along the train to assess its condition, the Cleveland East NS dispatcher informed the crew of reports that railcars were on fire. The conductor left the locomotive, saw smoke, and returned because of concerns about hazardous materials. The crew obtained permission from the NS Cleveland East dispatcher to separate the lead locomotives from the train and move to a safer distance.²¹ At 10:17 p.m., the crew moved the lead locomotives, placing them about a mile from the fires. At 10:26 p.m., they began a second movement, stopping the locomotives about 26 miles from the fires at 11:54 p.m.

Between 9:00 p.m. and 10:00 p.m., responders continued to contact NS personnel requesting train consist information, began evacuating residential buildings near the derailment site, and used the Wireless Emergency Notification System (WENS) to advise residents within 1 mile of the derailment to shelter in place.²² Shortly before 10:00 p.m., the NS northern regional hazmat manager emailed the consist for train 32N to the Columbiana County Emergency Management Agency (CCEMA) director, who had requested the information by phone.²³ Shortly afterward, through phone communication between NS and the EPPD, the deputy fire chief learned of two hazardous materials—benzene and VCM—in the train consist. When interviewed by the NTSB, the deputy fire chief said that he received the train

²¹ NS rules documented in the Hazardous Materials Instructions for Rail (usually referred to as HM-1), revised January 1, 2019, require train crews to move to a safe distance when fire or a vapor cloud is visible during a possible hazardous materials release.

²² WENS is a public safety system that allows customers who own compatible mobile devices to receive geographically targeted, text-like messages alerting them of imminent threats to safety in their area. Consumers do not need to sign up for this service. WENS allows government officials to send emergency alerts to all subscribers with WENS-capable devices if their wireless carrier participates in the program.

²³ CCEMA coordinated emergency management functions and disaster preparedness in Columbiana County, Ohio, where East Palestine is located. This included coordinating responses involving multiple local emergency response agencies, such as the EPPD, the EPPD, and fire and police departments from nearby communities.

consist “by word of mouth” on the night of the derailment but never received a physical or electronic copy.

About the same time as the first consist transmittal, the East Liverpool Fire Department fire chief was responding to the derailment and fire with a hazardous materials response team, having been activated at 9:24 p.m. When interviewed by the NTSB, he said that one of his technicians used a cell phone to access the AskRail application and obtain a copy of the train 32N consist before arriving on the scene at 9:54 p.m.²⁴ He also said in his interview that he received an emailed copy of the consist from the CCEMA director at 10:23 p.m. His team began working to determine which tank cars were involved with the fire, and the team concluded, based on the Emergency Response Guidebook (ERG), that the VCM “was the worst product involved,” although the team could not yet determine whether the VCM tank cars were burning or only exposed to fire. He recommended a 1-mile evacuation to the CCEMA director based on the ERG guidance. In the absence of radio interoperability between his team and the EPFD, he stationed one of his technicians in the command post to keep responders there informed while he was doing research and other activities that took him away from the command post. In his interview with the NTSB, he characterized the incident command as “fractured” and noted that, “what we talk about in the classroom and training programs versus what happens out in the field in the middle of chaos can be different.”

Between 10:15 p.m. and 10:30 p.m., the Beaver County hazardous materials response team arrived at the command post, having been contacted for assistance at 9:35 p.m. When interviewed by the NTSB, the Beaver County director of emergency services and chief of hazard materials, who was leading the Beaver County response team, said that the incident command was not yet well-defined:

And in that office, again, it was a train wreck, again it was a—there was chaos. So, the command may not well have been defined at that point, but it eventually got defined as far as the incident command.

He also told the NTSB that he attempted to access the AskRail application with a laptop to obtain a copy of the train consist once on the scene, but that the application did not work until about 2:00 a.m. on February 4, 2023. He reported sharing hazardous materials information to responding Beaver County fire

²⁴ (a) AskRail is a software application intended to provide pre-qualified personnel with information about train consists. The application is discussed in more detail in section 1.13.1.2. (b) The East Liverpool Fire Department fire chief and this technician arrived on the scene about 20 minutes ahead of the rest of the response team.

departments because of the “radio situation” that would cause issues with other means of providing that information. His team focused on air monitoring with photoionization detectors, which are devices designed to detect volatile organic compounds such as VCM, and on hazardous materials identification.

About 11:00 p.m. the deputy fire chief ordered a 1-mile evacuation through WENS and the federal Integrated Public Alert & Warning System.²⁵ Later, shortly after midnight on February 4, the East Palestine mayor made a separate announcement of the 1-mile evacuation at a news conference.

NS hazardous materials personnel arrived on the scene about 11:00 p.m., followed by NS contractors specializing in hazardous materials response and industrial firefighting, including Specialized Professional Services, Inc. (SPSI).²⁶ When interviewed by the NTSB, the SPSI president reported that upon arrival he observed a fire burning in a ditch on the south side of the tracks along the length of the pileup and smelled the distinctive odor of butyl acrylates.²⁷ Initial SPSI efforts focused on determining which materials were burning. These efforts were hampered by poor visibility, which made it difficult to identify individual tank cars. In interviews with the NTSB, responding firefighters reported that placards for several tank cars had been destroyed by the fire, and low light and smoke complicated attempts to determine which tank cars (and therefore which loadings) were being exposed to fire conditions.

About midnight, February 3-4, the NS northern region hazmat manager advised the deputy fire chief to suspend fire suppression activities and withdraw personnel and equipment to a safer distance. The deputy fire chief accepted this advice, issuing instructions to move all personnel and operations outside of a 1-mile perimeter of the accident site. His staff relocated the command post to the EPPD’s and EPPD’s shared station, slightly less than a mile from the derailment site. The relocation was complete by 2:00 a.m. on February 4.

²⁵ The Integrated Public Alert & Warning System is the Federal Emergency Management Agency’s national system for local alerting that provides information to the public through mobile phones, radio, and television.

²⁶ (a) The NS northern regional hazmat manager represented NS in the incident command early in the response, but various other NS personnel assumed that role over the course of the emergency response. (b) SPSI is an emergency response contractor and certified by The Chlorine Institute to respond to incidents involving VCM. NS contracted with SPSI and worked with them throughout the emergency response.

²⁷ Butyl acrylates are a flammable liquid. See section 1.8.5 for more information about this material. One derailed and mechanically breached tank car was carrying butyl acrylates.

The fire in the ditch south of the tracks continued to burn for about 3 hours after the derailment. The ditch fire ignited lading from tank cars containing butyl acrylates, ethylene glycol monobutyl ether, 2-ethylhexyl acrylate, propylene glycol, diethylene glycol, and petroleum lubricating oil; hopper cars containing plastic pellets (polyethylene and polyvinyl); and box cars containing various freights.²⁸ Excluding material released by PRDs on fire-exposed tank cars, these postderailment fires were fueled by the freight, lading, or components of 31 railcars. Fires fed by tank car lading continued to burn until the afternoon of February 4; fires involving hopper and box cars continued to smolder for several days after the derailment.

About 2:00 a.m. on February 4, 2023, the EPFD fire chief arrived on the scene and assumed the role of incident commander. According to his interview with the NTSB, he found a paper copy of the train consist on a table in the command post; this was the first time he obtained a complete copy. Events between train 32N reaching the East Palestine HBD and the arrival of the EPFD fire chief are summarized in a timeline in

²⁸ Butyl acrylates are a Class 3 flammable liquid, and ethylene glycol monobutyl ether and 2-ethylhexyl acrylate are combustible liquids. A detailed account of the hazardous materials involved in the derailment is provided in section 1.8. The other released loadings and plastic pellets can support combustion and caught fire, but they are not considered hazardous materials.

table 2.

Table 2. Timeline of HBD notification and early emergency response.

Date	Time	Event
2/3/2023	8:52 p.m.	Train 32N begins to traverse HBD at MP 49.81
2/3/2023	8:53 p.m.	HBD broadcasts a critical alarm for the L1 bearing on the hopper car
2/3/2023	8:53 p.m.	Crew begins to slow the train with dynamic braking
2/3/2023	8:54 p.m.	Train experiences an uncommanded emergency braking application
2/3/2023	8:56 p.m.	NS Cleveland East dispatcher confirms that train 32N has experienced an emergency
2/3/2023	8:56 p.m.	First 911 calls reach the EPFD PSAP (East Palestine dispatch)
2/3/2023	9:00 p.m.	EPFD personnel reach the derailment scene; deputy fire chief establishes first command post near derailment
2/3/2023	9:04 p.m.	East Palestine dispatch requests consist information from NS
2/3/2023	9:53 p.m.	Residents within 1 mile advised through WENS to shelter in place
2/3/2023	10:00 p.m.	NS emails consist to CCEMA director
2/3/2023	11:00 p.m.	Residents within 1 mile ordered through WENS to evacuate
2/3/2023	11:00 p.m.	NS hazardous materials personnel reach the scene, followed by contractors
2/4/2023	12:00 a.m.	Command post relocated to fire and police station
2/4/2023	2:00 a.m.	EPFD fire chief arrives and assumes incident commander role

1.1.3 Vent and Burn

By early morning on February 4, 2023, fire suppression activities had resumed with a focus on containment: unmanned streams of water were directed at exposed structures around the perimeter of the fire. No additional water was sprayed directly on the fire. Later on February 4, in consultation with NS and after reviewing a paper copy of the train consist, the fire chief shut down the unmanned streams.²⁹ By the morning of Sunday, February 5, the command post had been relocated a second time to a public school slightly more than a mile from the derailment site to accommodate all necessary personnel.

The derailed equipment included five mechanically intact tank cars carrying VCM and one mechanically intact tank car carrying isobutylene offered for shipment

²⁹ When interviewed by the NTSB, the EPFD fire chief reported that someone took his only copy of the consist, and that he asked NS for an emailed version, which NS provided.

as “UN1055, isobutylene, 2.1.”³⁰ All six were United States Department of Transportation (USDOT) Specification DOT-105J300W tank cars, usually referred to as DOT-105 tank cars. The isobutylene tank car (NATX35844) was positioned near the middle of the derailment pileup. One VCM tank car, OCPX80370 (line 55 in the consist), was positioned near the western end of the derailment pileup, exposed to a pool fire, and resting against a burning hopper car containing plastic pellets. The other four VCM tank cars—TILX402025 (line 28), OCPX80235 (line 29), OCPX80179 (line 30), and GATX95098 (line 31)—were positioned near the eastern edge of the derailment pileup. (See figure 7.) Tank car TILX402025 had come to rest between the two main tracks and was not directly exposed to a pool fire. Aerial images showed that the cover over the protective housing on TILX402025 remained closed during this period.³¹ The other three VCM tank cars at the eastern edge of the pileup were grouped together and exposed to postderailment fires.



Figure 7. Derailment pileup and VCM tank cars.

On the scene, NS and its contractor personnel derived information about the status of these tank cars from observation of PRD activity, visual assessment of tank cars, pressure readings, photoionization detector readings, and temperature measurements taken using an infrared thermometer.³² In interpreting these data, NS and contractor personnel referred to the safety data sheet (SDS) for VCM, the 2020 Emergency Response Guidebook (2020 ERG) published by the Pipeline and

³⁰ Isobutylene is a flammable gas in the same hazard class and division as VCM.

³¹ The cover extends over the PRD and other top fittings. Typically, a PRD actuation causes a cover to open. When a PRD on a tank car transporting a flammable material opens as a result of fire exposure, the released material will often ignite.

³² As discussed below, contractors were able to obtain pressure readings only from tank car TILX402025.

Hazardous Materials Safety Administration (PHMSA), and The Chlorine Institute's Pamphlet 171.³³

The first PRD actuation on a VCM tank car occurred shortly after midnight on February 4. A PRD actuates when the pressure inside a tank reaches the PRD's start-to-discharge pressure—a pressure high enough to open a valve held closed by a spring. The PRD opens until the tank's pressure falls low enough for the valve to re-close. A PRD on a tank car exposed to a pool fire will typically go through this cycle multiple times. PRD cycling continued for the four fire-exposed VCM tank cars until midafternoon on February 4, when the pool fires near four of the tanks had largely subsided. After 1.5-2 hours without visible PRD activity, the PRD on tank car OCPX80179 actuated about 5:30 p.m. and vented continuously for about 70 minutes. This venting was more energetic than other PRD actuations on the VCM tank cars. (See figure 8 for a comparison.) The PRD on tank car OCPX80179 eventually re-closed and did not actuate again. NS and contractor personnel did not observe any further PRD activity from the VCM tank cars.



Figure 8. PRDs venting material energetically (left) and more typically (right).

When interviewed by the NTSB, the SPSI president said that before the energetic PRD actuation on OCPX80179, NS and SPSI had been considering two methods of unloading VCM from the tank cars, hot tapping and flaring, and had already rejected a third, product transfer, because three of the VCM tank cars had damaged fittings. Each method is summarized below:

- Product transfer—transferring lading from the unloading valves and fittings of each damaged tank into a receiving tank

³³ A *safety data sheet* is a summary of hazards and precautions prepared by a chemical manufacturer, importer, or employer. The SDS and the other sources of guidance and hazard information, in general and regarding VCM specifically, are discussed section 1.8.1.1.

- Flaring—a controlled release of lading through a flare pipe (a device designed to gradually burn off flammable material at a safe location) attached to top fittings
- A hot tap—welding a threaded nozzle onto the tank and drilling through the tank wall to allow flaring or transfer even if the original unloading valves and fittings were damaged

In his interview with the NTSB, the president of SPSI noted that the top fittings of three VCM tank cars appeared damaged, which meant removing the product without cutting through the tanks would be impossible.³⁴ He also said that cutting into the tanks for flaring or hot tapping would be dangerous because they might have partially emptied, meaning that the flame of a cutting torch could impinge on the vapor space (the part of the tank filled with vapor rather than liquid lading) and result in a fire or explosion.

The SPSI president told the NTSB in his interview that he interpreted the energetic PRD activity to mean that polymerization had occurred in tank car OCPX80179, produced an increase in tank pressure, and “gummed up” the PRD, preventing it from functioning normally.³⁵ He also said that polymerization was another reason not to attempt transloading because the VCM was not in its original, as-shipped condition and might be unsafe to move to another packaging even if the VCM tank cars’ fittings were usable.

The SPSI president said that because of these concerns about polymerization affecting PRDs and the dangers of alternative methods of unloading, SPSI and NS “were already there at vent and burn in our minds” after 5:30 p.m. on February 4 based on their assessment of the energetic PRD actuation as indicating polymerization. The FRA characterizes a vent and burn as a last-resort method of unloading a damaged tank car, to be used only “when all other emergency product removal methods have been considered and rejected, and the consequences of not relieving the internal tank car pressure are determined to be greater than using this procedure” (FRA 1994). In a vent and burn, a tank car is punctured with explosives at

³⁴ In separate statements made during the NTSB Investigative Hearing, the president of SPSI said that the assessment of the valves’ condition was based on footage from drones, and he revised his count to four tank cars with damaged fittings. See NTSB Investigative Hearing, Day 1, pp. 228-29.

³⁵ (a) See also the SPSI president’s testimony at the NTSB Investigative Hearing Transcript, Day 1, pp. 145-46. (b) *Polymerization* is the process by which relatively small molecules (monomers) combine chemically to create larger chain- or network-like molecules (polymers). VCM polymerizes into polyvinyl chloride (PVC), a hard plastic.

the highest point in the tank to reduce the pressure in the tank car, then punctured with explosives at the lowest point in the tank to release lading. The released lading is directed through a trench and burned in a prepared pit. (See figure 9.) The president of SPSI told the NTSB in his interview that SPSI proposed venting and burning all five VCM tank cars even though not all five were showing signs of polymerization; in his stated opinion, the vent and burn procedure would result in a fire that could further damage any non-vented tank cars and make other methods of unloading more dangerous to contractor personnel.

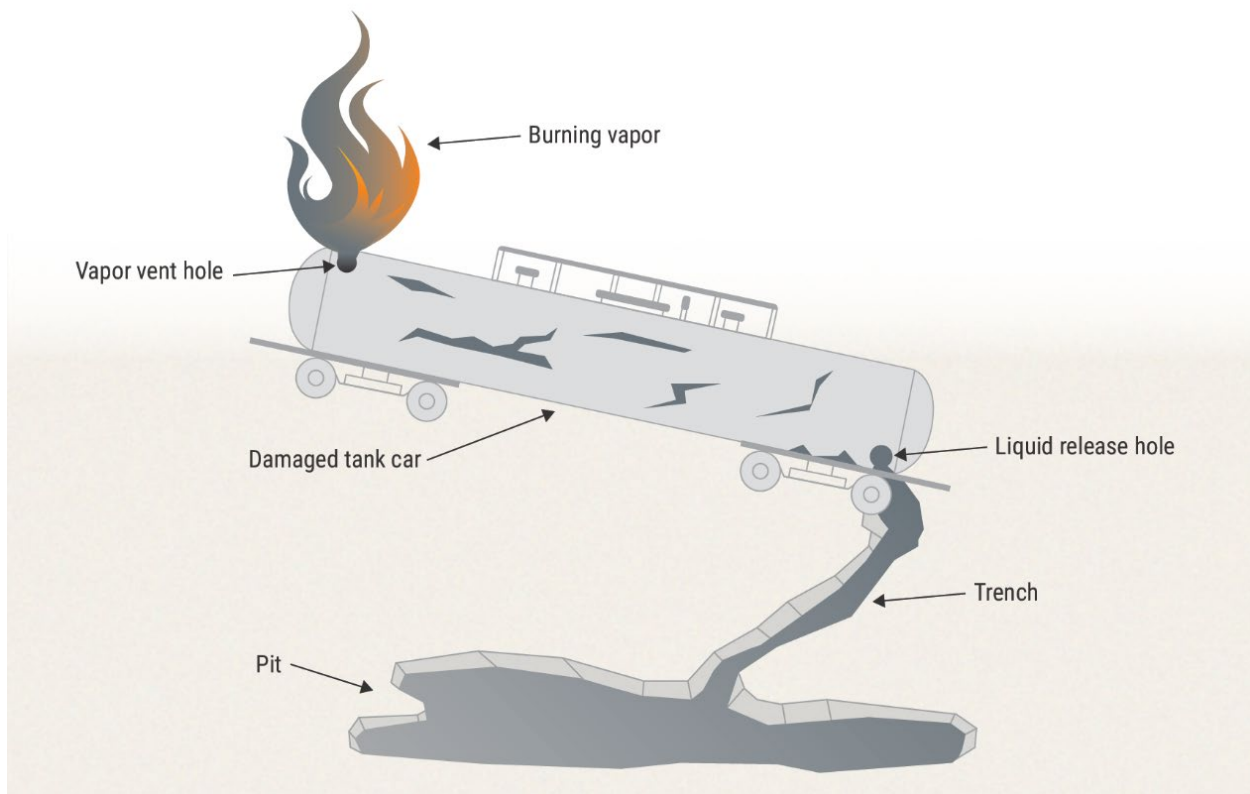


Figure 9. Illustration of a vent and burn procedure.

SPSI examined the VCM tank cars and attempted to measure their internal pressures on February 4. These examinations did not find indications that the tank cars had been mechanically breached or were releasing VCM except through PRDs. Because of the orientations of the tank cars and fire damage sustained by the top fittings, SPSI was able to obtain pressure measurements only from the easternmost VCM tank car, TILX402025 (line 28), which had not been exposed to the pool fire.³⁶

³⁶ *Top fittings* are part of a tank car's service equipment and include features like liquid and vapor valves and PRDs.

When interviewed by the NTSB, the SPSI president recalled that the February 4 afternoon pressure measurement was “unremarkable.” Another NS contractor, Specialized Response Solutions (SRS), began supporting the response on February 5 and also measured the internal pressure of tank car TILX402025.³⁷ The pressure measurements taken by SRS on February 5 indicated the tank’s contents were stable at 60 pounds per square inch gauge (psig).³⁸ In postaccident interviews with the NTSB, the SRS senior project manager present at the scene said that tank car TILX402025 appeared to be “fairly stable,” and that the contractors had developed a plan to clear that tank car from the tracks. He said that wrecking contractors who had been clearing railcars subsequently became concerned that the bolster assemblies on tank car TILX402025 had been damaged and decided to leave the tank car in place.³⁹

On February 4–5, NS contractor personnel also approached tank car OCPX80370 (line 55), the tank car on the western side of the derailment and resting against a burning hopper car, to assess its condition. On both days, contractor personnel noted no audible hiss indicative of gas being released from the PRD, but a photoionization detector indicated the presence of volatile organic compounds near the top fittings’ protective housing.⁴⁰ (VCM is a volatile organic compound.) When interviewed by the NTSB, the SPSI president said that he believed the PRD was leaking but not releasing enough flammable vapor to support combustion.⁴¹ Based on his observation, he thought that the VCM was polymerizing, causing the PRD to become plugged with polymer.

The shipper of all five VCM tank cars was Oxy Vinyls, LP, which had also manufactured the VCM. Under 49 *CFR* Part 172 Subpart G, anyone who offers a hazardous material for transportation must ensure the availability of emergency

³⁷ Like SPSI, SRS is an emergency response contractor certified by The Chlorine Institute to respond to incidents involving VCM. NS contracted SRS and worked with them throughout the emergency response from February 5 onward. Both SPSI and SRS also communicated directly with the incident commander as discussed in this section.

³⁸ A pressure in *psig* indicates relative pressure—in this case, the difference in pressure between the interior of the tank and the outside atmosphere.

³⁹ In a tank car, the *bolster* is the component that bears the weight of the tank.

⁴⁰ A *photoionization detector* is a type of gas detector. Typical photoionization detectors measure the concentration of volatile organic compounds.

⁴¹ It is common for PRDs to become damaged during operation and begin leaking (releasing vapor without actuating) or discharging below their original start-to-discharge pressures.

response information (ERI) on the shipping paper or a document such as an SDS, including the basic description and technical name of the hazardous material, hazard information, and immediate precautions to take following an accident or incident. The offeror must also provide an emergency response telephone number that is monitored by a person who is knowledgeable about the hazardous material being shipped and has comprehensive emergency response and incident mitigation information for that material or has immediate access to a person who possesses that knowledge and information.

Oxy Vinyls provided an emergency response telephone number through CHEMTREC, a third-party company that operates a 24-hour call center for emergencies involving hazardous materials. An NS hazmat officer contacted CHEMTREC at 7:58 a.m. on February 4 and requested a copy of the SDS and a callback from the shipper. At 8:22 a.m. on the same day, CHEMTREC contacted Oxy Vinyls and facilitated communications between the two entities.

NS and SPSI first communicated directly with Oxy Vinyls, about 6:00 p.m. on February 4, in a conference call that included Oxy Vinyls' special situation team and four managers based in Dallas, Texas. During the conference call, Oxy Vinyls assessed a low probability of polymerization based on the observed PRD behavior but recommended monitoring the tank cars for an increase in temperature that could indicate an exothermic reaction.⁴² Oxy Vinyls also recommended using modeling to assess the possible consequences of a tank car failure.

CTEH, another of NS's contractors, used the Complex Hazardous Air Release Model software program to produce theoretical tank car failure outcomes on the morning of February 5.⁴³ CTEH distributed the model results to NS at 4:15 a.m., and NS shared the results with the incident commander at 7:41 a.m. The modeled outcome was based on a type of tank car failure called a boiling liquid expanding vapor explosion (BLEVE). A BLEVE occurs when a tank car containing a liquified compressed gas (such as VCM) fails to contain its internal pressure. The loss of pressure results in a rapid decrease in the boiling point of the formerly pressurized liquid, which vaporizes and expands explosively, leading to a sudden and energetic product release. The Complex Hazardous Air Release Model developed at East

⁴² An *exothermic* chemical reaction is one that produces heat.

⁴³ The Complex Hazardous Air Release Model is a modeling program that calculates the footprints of various chemical release effects, such as thermal radiation and overpressures.

Palestine indicated that tank car debris could be propelled about half a mile if a BLEVE occurred.

At 2:00 p.m. on February 5, three representatives from Oxy Vinyls arrived on the scene to provide technical assistance regarding the characteristics of VCM: a technical manager, a logistics process supervisor, and an emergency services lead. These representatives met with SPSI and SRS personnel and discussed the location and conditions of the derailed tank cars, the temperature measurements, and concerns about polymerization. The NTSB obtained the substance of the meeting from postaccident interviews with the participants. During the meeting, the Oxy Vinyls technical manager said that if polymerization occurred, it could lead to obstruction of a PRD, but that he was not an expert on polymerization. The Oxy Vinyls logistics process supervisor said the VCM was loaded under a nitrogen blanket to displace oxygen because oxygen could promote polymerization. If heated to about 185°F, the tank would reach a pressure high enough to actuate a PRD, but this actuation would not introduce oxygen. While PRD operation could expel nitrogen along with VCM, there would be no way for oxygen to enter the tank as long as the tank remained above atmospheric pressure. The SPSI president communicated that SPSI and SRS were asking about polymerization resulting in tank failure because the 2020 ERG and the Oxy Vinyls SDS listed polymerization as a potential hazard.

When discussing the possibility of a vent and burn or other means of unloading the VCM, Oxy Vinyls' technical manager estimated that for every 62 pounds of vinyl chloride burned in a fire, about 36 pounds of hydrogen chloride would be generated.⁴⁴ He suggested that flue gases from combusting vinyl chloride should go through a scrubber if NS chose to flare the tank cars.⁴⁵

The NTSB had a brief conversation with the Oxy Vinyls on-scene representatives after this meeting to gather information for our investigation. The NS hazardous materials regional manager was present during the conversation. When discussing the possibility of a BLEVE resulting from polymerization, the Oxy Vinyls

⁴⁴ *Hydrogen chloride*, or HCl, is a colorless gas at room temperature that forms hydrochloric acid upon contact with water, including atmospheric water vapor and water in body tissue. The National Fire Protection Association's *NFPA 704: Standard System for the Identification of the Hazards of Materials for Emergency Response* classifies hydrogen chloride as corrosive and a level 3 health risk, meaning that short exposure could cause serious temporary or moderate residual injury (NFPA 2022).

⁴⁵ (a) A *scrubber* is an apparatus for purifying gases or vapors. (b) *Flaring* is a method of lading removal that involves burning lading at a safe location. (c) A flare was not performed on any of the tank cars involved in this accident.

representatives indicated that they had never had an incident lead to a BLEVE and were not sure what the outcome would be.⁴⁶

Following Oxy Vinyls' earlier conference call recommendation to monitor the tank cars for an increase in temperature, SPSI and SRS began to monitor the temperatures of all five VCM tank cars about 4:00 p.m. on February 5. Under normal conditions, tank car lading temperatures are obtained by inserting a probe into the thermometer well, a narrow tube situated among the tank car's top fittings that extends into the lading. The process requires personnel to work in close proximity to the tank car's top fittings. At East Palestine, contractor personnel used infrared thermometers. The resulting measurements are shown in table 3. Tank car OCPX80370 was showing an elevated temperature. The other four VCM tank cars exhibited lower measured temperatures. Although the temperature measurements were used by NS and its contractors to assess the likelihood of polymerization, the opinions offered at the NTSB Investigative Hearing by the SPSI president and the Oxy Vinyls vice president of health, environment, safety, and security differed regarding the accuracy of the temperature readings. The SPSI president testified that he did not have high confidence in the temperature readings because pieces of jacket or thermal protection blanket might have been interfering with their attempts to take the temperature of the bare tank shell and because the temperature measured at one point on the shell might not accurately reflect temperatures across the entire tank car.⁴⁷ However, the Oxy Vinyls vice president of health, environment, safety, and security testified that he believed the temperature monitoring method SPSI used was valid for assessing whether polymerization was progressing.⁴⁸

⁴⁶ As further discussed below, Oxy Vinyls was not yet a party to the investigation and not involved in the formal investigative progress meetings.

⁴⁷ (a) NTSB Investigative Hearing Transcript, Day 1, pp. 149-50. (b) *Jackets and thermal protection blankets* are features intended to protect a tank car during an accident. Tank car protection is discussed in more detail in section 1.7.1.

⁴⁸ NTSB Investigative Hearing Transcript, Day 1, pp. 173-75.

Table 3. SPSI tank car temperature measurements.

Date	Time	TILX402025 Temperature (°F)	OCPX80235 Temperature (°F)	OCPX80179 Temperature (°F)	GATX95098 Temperature (°F)	OCPX80370 Temperature (°F)
2/5/2023	4:00 p.m.	65	65	65	67	135
	5:00 p.m.	-	-	-	-	138
	6:00 p.m.	-	-	-	-	136
	7:00 p.m.	-	-	-	-	136
	8:00 p.m.	-	-	-	-	130
	9:00 p.m.	-	-	-	-	130
	10:00 p.m.	-	-	-	-	130
	11:00 p.m.	-	-	-	-	131
2/6/2023	12:00 a.m.	65	65	65	67	139*
	1:00 a.m.	65	65	65	67	129
	2:00 a.m.	-	-	-	-	-
	3:00 a.m.	-	-	-	-	-
	4:00 a.m.	-	-	-	-	-
	7:00 a.m.	62	63	90	115	120
	8:37 a.m.	62	65	65	65	127
	9:30 a.m.	65	65	65	65	126
	10:30 a.m.	65	65	65	65	126
	11:30 a.m.	65	65	65	65	126
	12:30 p.m.	65	65	65	65	126
	1:30 p.m.	65	65	65	65	126
	2:30 p.m.	65	65	65	65	126

*When interviewed by the NTSB, the EPFD fire chief noted that this increase in temperature coincided with the ignition of a small fire underneath tank car OCPX80370, and that the temperature decreased after the fire was extinguished.

On the afternoon of February 5, the Oxy Vinyls technical manager joined a conference call with off-site Oxy Vinyls personnel, including the special situations team in Dallas. When interviewed by the NTSB, the Oxy Vinyls technical manager said that the participants in the call reached a consensus that available evidence did not indicate polymerization within the tank cars: the tank cars had been loaded with an oxygen concentration too low to support polymerization, the temperatures measured on the tank cars' shells were lower than those a polymerization reaction would produce, and the PRDs could have stopped cycling because the temperature was below that which would produce vapor pressure sufficient to actuate the PRD. When interviewed by the NTSB, the Oxy Vinyls vice president of health, environment, safety, and security, who was also on the call, said that the participants also believed a

significant proportion of lading had already been vented from three VCM tank cars exposed to fires.

Around the same time, the SPSI president met with the NS system manager for hazardous materials and the SRS senior project manager. When interviewed by the NTSB, the SRS senior project manager said they concluded that polymerization was occurring within VCM tanks because of fire exposure and that the best option was a vent and burn. NS and its contractors began preparations to vent and burn the VCM tank cars. Between 3:00 p.m. and 5:00 p.m., the SRS senior project manager requested a response from an explosives contractor, Explosive Service International (ESI), while other contractors began excavating containment pits to receive VCM released during the vent and burn.⁴⁹ During these preparations, a sweep of the scene by NS contractors found no evidence that the VCM tank cars had been mechanically breached, and the residual fires were mostly under control.

At 5:47 p.m. on February 5, SPSI and SRS contacted the incident commander and said that circumstances might require a vent and burn of the VCM tank cars. In postaccident interviews with the NTSB, the SRS senior project manager said that the reasons not to attempt another method of unloading the tank cars—their damaged condition and the risk of polymerization—also supported venting and burning all five simultaneously. He said that venting and burning only some of the tank cars would have required personnel unloading the others to work near damaged tank cars and dangerous polymerization reactions. In the incident commander's postaccident interview with the NTSB, he said:

It was explained to me that...how those cars were, that they couldn't single out one car and safely vent and burn it without the possibility of something happening to the other cars. And again, that one car, two car, three car, five car, there was a lot of discrepancy in my opinion about what they were going to do as far as the vent and burn in that process. Different people had said different things. We're only going to do one. We're going to do two. We're going to do five. And I don't feel

⁴⁹ (a) ESI is not affiliated with Engineering Systems, Inc. (ESI), a separate company that examined rail equipment recovered from the derailment. (b) The timing of the communication between the SRS senior project manager and ESI is based on the ESI president's interview with the NTSB. The ESI president was in Louisiana when he received the call from SRS, and it is not clear in his interview whether his stated "around three or four o'clock in the afternoon" is in Central Time or Eastern Time. The time range shown in the report reflects this uncertainty.

that I comfortably had an answer to that 100 percent until we discussed that final discussion of the vent and burn process.

The incident commander said that he had been informed that safety devices were definitely not functioning on one tank car and were potentially not functioning on another.

About 6:00 p.m. on February 5, during a meeting with the NTSB to provide a progress update on the investigation, the NS systems manager for hazardous materials told the NTSB that VCM was polymerizing and obstructing PRDs, preventing them from functioning. He said that the temperature of one tank car, OCPX80370, had risen 3°F in 1 hour to 138°F, indicating a polymerization reaction. He also said that if the tank shell temperature rose to 185°F, the VCM would have reached the critical temperature for a runaway polymerization reaction, information he attributed to Oxy Vinyls.⁵⁰ NS assessed the most likely outcome of continuing polymerization was an explosion capable of propelling tank car fragments up to half a mile and producing large amounts of radiant heat. NS communicated to the NTSB that it favored a vent and burn to prevent this explosion.⁵¹

During the same conversations with the NTSB during the investigative progress meeting, the NS systems manager for hazardous materials described the three alternatives to a vent and burn (product transfer, hot tapping, and flaring) that NS and SPSI had rejected as unsafe because of the tank cars' unknown internal pressures and unknown extent of damage. The Oxy Vinyls representatives were not present at the investigative progress meeting, and Oxy Vinyls was not yet a party to the investigation.

About 7:00 p.m. on February 5, the Oxy Vinyls on-scene representatives met with SPSI, where they learned that SPSI had chosen a vent and burn as the best response. (NS had requested that Oxy Vinyls communicate through SPSI, which was in contact with NS.)⁵² When interviewed by the NTSB after the accident, the Oxy Vinyls technical manager said that SPSI did not ask for Oxy Vinyls' opinion on the vent

⁵⁰ As discussed above, the Oxy Vinyls logistics process supervisor previously told SPSI and SRS that 185°F was the temperature that would result in pressures high enough to actuate a PRD on a VCM tank car. The NTSB did not find evidence of statements from Oxy Vinyls about 185°F being a critical temperature for polymerization.

⁵¹ This meeting, like other on-scene meetings involving the NTSB, was in support of the investigation. The NTSB was not involved in the emergency response.

⁵² NTSB Investigative Hearing Transcript, Day 1, p. 177.

and burn. Oxy Vinyls told SPSI that it did not interpret the available information as evidence of polymerization, as decided during the afternoon conference call with the special situations team in Dallas. The technical manager stated that the SPSI president responded by explaining his reasons for favoring the vent and burn, including his concerns about trying to transfer VCM from tank cars of unknown structural integrity.

When interviewed by the NTSB, the Oxy Vinyls vice president of health, environment, safety, and security, stated that during this meeting with SPSI, the Oxy Vinyls vice president of manufacturing told SPSI:

...we're not on the ground with you, so if you're talking about a vent and burn decision, don't do it because of polymerization, because polymerization is not occurring, that was the gist. So, he was just trying to communicate [that a] vent and burn may have other motivators for it, but don't do it because of polymerization because it's not occurring and he was pretty absolute with that statement.

When interviewed by the NTSB, the Oxy Vinyls technical manager said that Oxy Vinyls did not formally approve or disapprove of the decision to vent and burn because it was not their role to recommend mitigation techniques. At the NTSB's Investigative Hearing, he testified that he was confident while on the scene that Oxy Vinyls' positions were being communicated to the full incident command.⁵³

Shortly after noon on February 6, the incident command met to determine whether the vent and burn method was the best available option to mitigate the risk of an uncontrolled explosive tank rupture. This meeting involved an estimated 60-100 individuals, including people and organizations not part of the formal incident command, such as the governors of Ohio and Pennsylvania. Representatives from Oxy Vinyls were not present and had not been invited to attend. The NTSB did not find evidence that attendees other than NS and its contractors were aware that Oxy Vinyls had developed a dissenting opinion about polymerization. According to the incident commander's postaccident interview with the NTSB, no attendee objected to conducting the vent and burn based on the information presented and the potential BLEVE hazard as characterized by NS, SPSI, and SRS. The SPSI president and SRS project manager told the incident commander that the VCM was undergoing

⁵³ NTSB Investigative Hearing Transcript, Day 2, p. 253.

polymerization, was generating its own heat, and was unstable because of the elevated temperatures.⁵⁴

Shortly after the incident command meeting, the incident commander focused on ensuring that appropriate residential evacuations were underway in preparation for a possible vent and burn. Once the Ohio and Pennsylvania governors were satisfied that evacuations were completed, an NS representative asked the incident commander and the Ohio governor to meet in a separate room with NS, SPSI, and SRS personnel, including the chief executive officer of NS. When interviewed by the NTSB after the accident, the incident commander reported that the SPSI president and SRS project manager said in this meeting that he had 13 minutes to decide whether to allow them to proceed with the vent and burn because they wanted to begin before 3:00 p.m. to avoid the effects of atmospheric temperature inversion and allow the vapor cloud to disperse. The incident commander said that he felt overwhelmed and blindsided by the size of the decision and significant time constraint. Before agreeing to proceed, the incident commander asked SPSI and SRS to explain the vent and burn process and to repeat why it was necessary. The SPSI president and SRS project manager told the incident commander that if a tank car's temperature rose to 150°F, for safety reasons they would withdraw personnel from the area and stop any attempt to prevent an uncontrolled explosive tank rupture. They also told the incident commander that if the temperature in a tank car reached 153-158°F, the result would be an uncontrolled polymerization reaction accompanied by a rapid rise in temperature.⁵⁵

By the time of the meetings on February 6, the highest tank car temperatures had fallen from about 138°F the previous afternoon to about 126°F. When interviewed by the NTSB, the incident commander said the declining tank car temperatures did not impact SPSI's and SRS's urgency to conduct a vent and burn; SPSI and SRS were more concerned with the need to finish the procedure during daylight hours. Hearing no objections from anyone present during the meetings on the morning of February 6, and given the statements from NS, SPSI, and SRS that the vent and burn procedure was the only remaining option to avoid a catastrophic BLEVE, the incident commander consented to proceeding with the vent and burn. In interviews with the NTSB, the incident commander said that he bore the responsibility for this decision, and in his testimony at the NTSB's Investigative Hearing, he noted

⁵⁴ Based on SPSI and SRS temperature measurements, the hottest tank car, OCPX80370, had decreased in temperature from its peak of 138°F to about 126°F by the afternoon of February 6.

⁵⁵ The NTSB did not find this temperature range in written guidance about VCM consulted at the scene or in communications between Oxy Vinyls and NS and NS contractors.

the need to make the decision quickly based on the input from NS, SPSI, and SRS that there was no other option to prevent catastrophic failure of a tank car.⁵⁶

According to the incident commander, no Oxy Vinyls employees were invited to these meetings, and none were present. Nor did any Oxy Vinyls employees communicate with the incident commander outside these meetings.

The vent and burn was originally scheduled for 1:00 p.m. on February 6, 2 hours ahead of the 3:00 p.m. deadline described to the incident commander by SPSI and SRS. However, the vent and burn was repeatedly delayed for technical and safety reasons: once to rewire the charges and three times because of unauthorized persons entering the evacuation zone. ESI detonated the vent and burn charges at 4:37 p.m. for all five VCM tank cars, puncturing each tank car at two points: the highest point in the vapor space and the lowest point where the liquid had pooled. The punctured tank cars expelled vapor, which was ignited by flares positioned near each tank car. Burning VCM resulted in a column of black smoke that grew into a persistent cloud. (See figure 10.) According to the NS system manager for hazardous materials, the cloud likely contained soot particles, carbon dioxide, carbon monoxide, hydrogen chloride, and a trace of phosgene (a toxic gas).

⁵⁶ NTSB Investigative Hearing Transcript, Day 2, p. 139.



Figure 10. The vent and burn 3 minutes after detonation. (Courtesy of NS.)

NS began wreckage clearing on February 7 following assessment of the isobutylene tank car that had come to rest between OCPX80370 and the eastern group of VCM tank cars. The isobutylene tank car was successfully moved to an adjacent staging area on February 7 and transloaded on February 22, after the vent and burn of the VCM tank cars.

NS resumed rail service through East Palestine on main track 2 (adjacent to the derailment site) on February 8, and the first train passed through the derailment site at 4:46 p.m. At 5:28 p.m. on February 8, the incident commander lifted the evacuation order as a result of meetings with the governors of Ohio and Pennsylvania, the Environmental Protection Agency, and the Centers for Disease Control and Prevention. Trains began using main track 1 on the morning of February 9. Table 4 provides a summary of the vent and burn timeline.

Table 4. Timeline of vent and burn decision.

Date	Time	Event
2/4/2023	Early morning	First PRD actuations on VCM tank cars
2/4/2023	Midday	PRD actuations cease
2/4/2023	5:30 p.m.	PRD on tank car OCPX80179 actuates and vents energetically and continuously for about 70 minutes
2/4/2023	After 5:30 p.m.	SPSI and NS are “already at a vent and burn” according to the SPSI president’s interview with the NTSB
2/4/2023	6:00 p.m.	Conference call between SPSI, SRS, and off-scene Oxy Vinyls personnel; Oxy Vinyls recommends monitoring tank car temperatures
2/5/2023	2:00 pm.	Oxy Vinyls representatives arrive on the scene and meet with SPSI and SRS personnel
2/5/2023	4:00 pm.	Temperature monitoring begins
2/5/2023	Afternoon	Oxy Vinyls on-scene and off-scene teams reach consensus that polymerization is not occurring in fire-exposed VCM tank cars
2/5/2023	Between 3:00 p.m. and 5:00 p.m.	SRS asks ESI to travel to the scene in preparation for a vent and burn
2/5/2023	5:47 p.m.	SPSI and SRS recommend a vent and burn to the incident commander
2/5/2023	6:00 p.m.	NS tells the NTSB during an investigative update meeting that polymerization is occurring and that it is proposing a vent and burn
2/6/2023	Early afternoon	Incident command meets to discuss the vent and burn (Oxy Vinyls is not in attendance)
2/6/2023	Early afternoon	EPFD incident commander, Ohio governor, NS, SPSI, and SRS personnel have a separate meeting; the incident commander asks additional questions and agrees to the vent and burn; the incident commander is not aware that Oxy Vinyls has offered a dissenting opinion on polymerization
2/6/2023	1:00 p.m.	Proposed time for vent and burn
2/6/2023	4:37 p.m.	Charges detonate to vent all five VCM tank cars
2/8/2023	4:46 p.m.	The first train passes through the derailment site on main track 2
2/8/2023	5:28 p.m.	Evacuation lifts
2/9/2023	Morning	NS resumes rail service on main track 1

1.2 Norfolk Southern Railway

NS is categorized as a Class I railroad under the Surface Transportation Board regulations (49 CFR 1201).⁵⁷ NS operates about 19,420 route miles of track in 22 states and has rights in Canada over the Albany, New York, to Montreal, Ontario, route owned by Canadian Pacific Kansas City Limited. NS is a subsidiary of the Norfolk Southern Corporation and is headquartered in Atlanta, Georgia.

1.3 Data Recorders

The NTSB received event recorder files from the lead locomotive and the distributed power unit, which were equipped with model F3050 Central Railway MFG event recorders. These files included data from train 32N's movements leading up to the derailment and the derailment itself.

The NTSB received locomotive image recorder data provided by NS from five sources. Three of these sources were aboard the lead locomotive, and two sources were aboard the second locomotive. The provided files included audio and video data from about 15 minutes before the derailment, the derailment itself, and about 6 minutes after the derailment. The source, file count, and camera direction for each source are shown in table 5.

Table 5. Summary of image recorder information.

Camera	Locomotive	Number of Files	Total Video Length (minutes:seconds)
External forward facing	Lead	21	20:59
Inward rearward facing	Lead	19	19:00
Inward forward facing	Lead	21	20:59
External forward facing	Second	1	20:02
Inward forward facing	Second	1	20:01

The NTSB requested but did not receive additional image and audio data as described in

⁵⁷ *Railroad classes I through III are defined by annual revenue. Of the three classes, Class I railroads have the highest annual revenues, currently defined as \$900 million or more.*

table 6.

Table 6. Timeline of recorder data requests and action.

Date	Time	Event
2/4/2023	7:30 a.m.	NTSB advises NS to hold and preserve all evidence
	1:30 p.m.	NTSB investigator in charge arrives at incident command post and requests full download of locomotive event and image recorders
	7:00 p.m.	NTSB investigator in charge discusses preservation and collection of image recorder data and possible on-scene viewing of forward-facing image recorder data
2/5/2023	6:00 a.m.	NTSB again requests inward- and forward-facing image recorder data from NS
	N/A	NTSB examines lead locomotive and finds that the image recorder memory modules have been removed and are sitting on the control console
	N/A	NS tells the NTSB that event and image recorder information has been uploaded to the shared file database for the investigation
	6:00 p.m.	NS shows NTSB and other parties about 10 minutes of data from the lead locomotive's forward-facing image recorder
2/13/2023	N/A	NTSB contacts NS about image recorder data, which have not yet been uploaded to the shared file database
	N/A	NS uploads the image recorder data; NTSB confirms that the data uploaded successfully
2/15/2023	3:00 p.m.	NTSB conducts formal audition of inward- and forward-facing image recorder data and finds about 30 minutes of data
	Afternoon	NTSB requests additional data to include the last four HBDs traversed by train 32N
2/16/2023	N/A	NS reports that no further image recorder data are available because the locomotives were returned to service, and their onboard recorders only included data going back to 2/10/2023
2/24/2023	10:40 a.m.	NTSB requests at least 24 hours of event recorder data including the derailment
	Noon	NS uploads 24 hours of event recorder data into the shared file service for the investigation, including data from 2/3/2023

1.4 Track and Signals

The derailment occurred on the NS Keystone–Fort Wayne Line, which extends from milepost MP 0 to MP 188 in an east-west direction and consists mostly of double main track. According to information provided by NS to the FRA on August 12, 2022, about 46 trains pass through East Palestine each day on the NS Keystone–Fort Wayne Line. Train movements near the derailment site are authorized by cab signal indications with an overlaid positive train control (PTC) system and coordinated by an

NS train dispatcher at the Dispatch Center in Atlanta, Georgia.⁵⁸ The NTSB's review of PTC data logs from train 32N did not identify issues with signal function on this line.

The track where the derailment occurred is designated Class 4 under Federal Railroad Administration (FRA) regulations, which allows a maximum speed of 60 mph for freight trains and 80 mph for passenger trains (49 CFR 213.9).⁵⁹ However, NS had permanently restricted the maximum authorized timetable speed for all trains to 50 mph.⁶⁰

During the investigation, the NTSB reviewed NS track inspection records. Main track 1 near the derailment site was last inspected with rail flaw detection equipment on January 16, 2023; this inspection did not identify any safety-relevant rail defects. The track was visually inspected as required by 49 CFR 213.233 on January 31, 2023, and February 1, 2023; these inspections identified one track condition in need of repair 24.1 miles west of the derailment site (a broken switch component). The switch component had been repaired before train 32N passed over the switch on the day of the derailment.

On February 4, 2023, the NTSB performed a walking inspection on main track 1 between MP 51 and MP 49, which included the track between the East Palestine HBD and derailment site. The NTSB did not identify any track defects. During this walking inspection, the NTSB identified scrape-like markings on the top of the south running rail at MP 49.5. (See figure 11.) The markings were consistent with the side frame of a truck or similar railcar component sliding along the top surface of the railhead during a derailment.⁶¹ Additional scrape-like markings extended 1,464 feet east from MP 49.5 along the south running rail. The crossties in this area exhibited grooves within the gage consistent with derailed wheel flanges running along the ground.⁶² (See figure 12.) There were no similar markings west of MP 49.5.

⁵⁸ A *positive train control system* enforces speed limits and prevents a train from passing through a signal that requires it to stop.

⁵⁹ Track classes are categorized based on their speed limits.

⁶⁰ Instructions limiting train speeds were documented in the NS Pittsburgh Division Timetable. It is common for railroads to restrict speeds to below FRA maximums for safety reasons.

⁶¹ A *side frame* is part of the truck. Each railcar has two trucks, and each truck contains two wheelsets. During normal operation, a side frame does not contact the running rail.

⁶² *Gage* refers to the distance or space between the running rails. *Gage side* means the side of the rails toward the center of the track. *Field side* means the outward side.

The grooves and markings on the rail were consistent with a point of derailment at MP 49.5.



Figure 11. South running rail at MP 49.5.



Figure 12. Wheel flange marks on cross-ties east of MP 49.5.

The NTSB documented track geometry west of MP 49.5.⁶³ The NTSB did not identify any lateral or longitudinal rail movement, out-of-tolerance gage measurements, abnormal vertical rail deflection, or measurements deviating from NS's engineering design standards, curve specifications, or track profile charts.

1.5 Wayside Bearing Defect Detection

Wayside bearing defect detectors are devices intended to alert railroads to failing bearings in time to prevent a derailment or other accident. The two most common devices currently in use are HBDs and acoustic bearing detectors (ABDs).

⁶³ *Track geometry* refers to the gage, surface, and alignment of the track structure—physical characteristics that inform how vehicles interact with the track.

HBDs measure bearing temperatures and identify bearings in the process of overheating; ABDs monitor bearings for potential flaws by evaluating each bearing's acoustic signature as it passes wayside microphones. ABDs are intended to identify early signs of bearing degradation and allow railroads or railcar owners to service or replace bearings before they fail.

Wayside bearing defect detection systems are currently deployed by railroads voluntarily—all six Class I railroads use them—and are not regulated by the FRA. The Association of American Railroads (AAR) provides some guidance on the use of wayside bearing defect detection, but as discussed below in section 1.5.4, individual railroads vary in their approaches.

1.5.1 Wayside Bearing Defect Detector Equipment and Configuration

At the time of the East Palestine derailment, the average interval between HBDs in NS's rail network was about 13.9 miles.⁶⁴ The three HBDs train 32N traversed shortly before the derailment were Progress Rail Micro models configured to measure bearing temperatures 7.25 inches outboard of each running rail's inner edge, or near the inner edge of each bearing cup, with the infrared camera oriented 45° above the plane of the running rail.⁶⁵ (See figure 13 and figure 14.) At the East Palestine Investigative Hearing, the founding director of the University Transportation Research Center testified that changes to bearing temperature as measured on the exterior of the bearing cup tend to lag behind temperature changes in the bearing's interior.⁶⁶ An increase in temperature within the bearing may take 30 minutes to an hour to be accurately reflected by a temperature reading taken on the exterior of the bearing cup.

⁶⁴ Note that an average interval between detectors is not necessarily a typical interval; detectors can be closely spaced throughout some stretches of track but loosely spaced elsewhere.

⁶⁵ The *bearing cup* is the cylindrical housing that contains the rollers and other bearing components that move relative to the railcar.

⁶⁶ NTSB Investigative Hearing Transcript, Day 2, pp. 219-20.



Figure 13. Example of a Progress Rail Micro HBD.

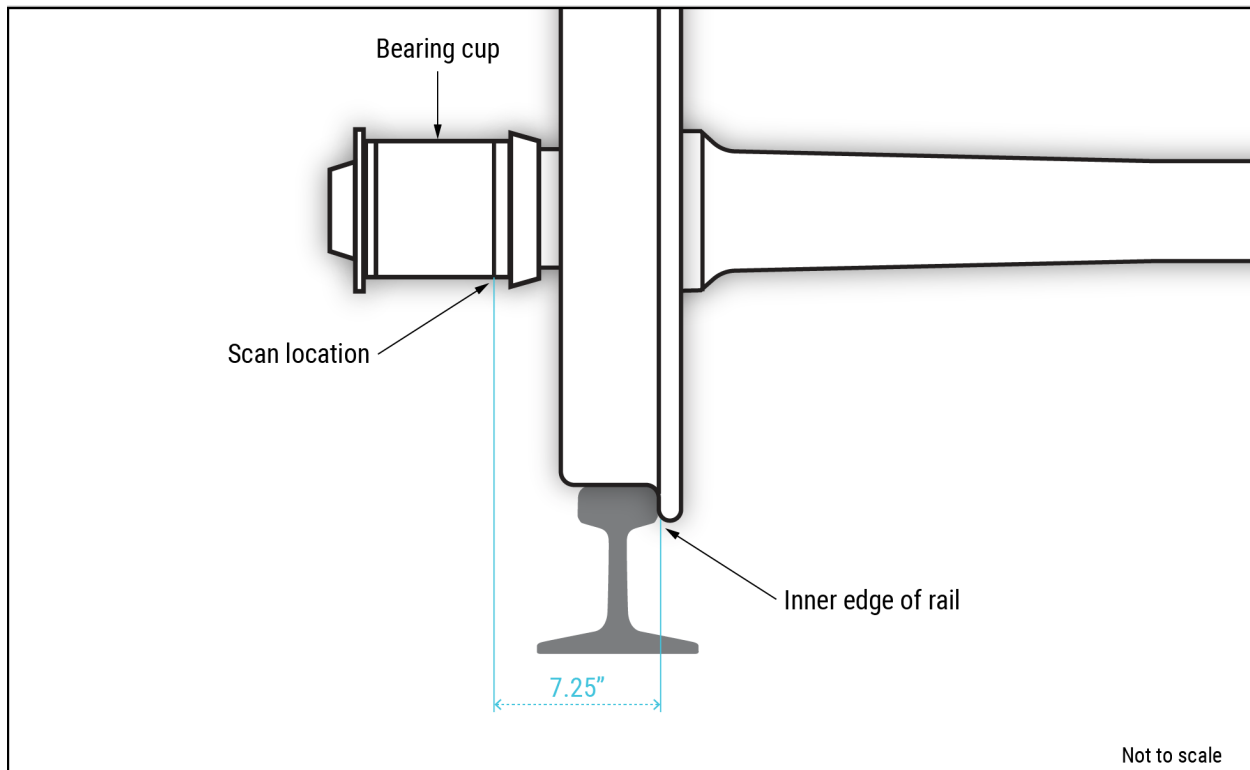


Figure 14. Diagram of HBD scan location.

1.5.2 NS Wayside Help Desk

All NS wayside detectors are monitored from the NS ATC Wayside Help Desk in Atlanta, Georgia. At the time of the East Palestine derailment, the Wayside Help Desk was staffed by single analysts working 12-hour shifts. An algorithm processes data from multiple HBDs and automatically displays alerts on the analyst's console. NS standard operating procedures establish alert criteria for temperature measurements and trends and specify analyst responses to various types of alerts as described in section 1.5.3.1.

1.5.3 NS Wayside Detector Alert and Alarm Criteria

1.5.3.1 NS Hot Bearing Alert and Alarm Criteria

NS divides abnormal HBD readings into two categories: alerts and alarms. Alerts are displayed on the Wayside Help Desk console and not broadcast directly to train crews. Alerts are triggered by any one of the following criteria:

- An HBD reading of 90°F or more above ambient with a Kt value greater than four;

- Readings that indicate a bearing is significantly warmer than other bearings on the same side of the train (an elevated Kt value) or the same piece of equipment (an elevated Ke value) even if the bearing has not exceeded 90°F; or
- A temperature differential of 115°F or more between bearings on the same axle.⁶⁷

Not all alerts require that an analyst instruct the crew to stop and inspect the train. Under NS standard operating procedures, an analyst must give this instruction only for critical alerts, which occur if the Ke or Kt value for a single bearing exceeds four during a train's journey three times, or if the analyst receives a temperature differential alert. For alerts that do not meet these criteria (non-critical alerts) the analyst must instead monitor the affected train as it traverses subsequent HBDs to conduct a trend analysis of the suspect bearing's temperature.

An alarm is radioed directly to a train's crew by the HBD itself when the HBD detects a bearing temperature between 170°F and 200°F above ambient (a "warm bearing" alarm); the audible alarm communicates the type of alarm and location of the warm bearing. When a crew receives a warm bearing alarm, NS operating rules require the crew to reduce the train's speed until the last railcar has passed the HBD, then stop the train to inspect the affected wheelset.⁶⁸ An alarm is also triggered when the HBD detects a bearing temperature more than 200°F above ambient (a "critical bearing" alarm). When a crew receives a critical bearing alarm, NS operating rules require the crew to bring the train to a safe stop immediately to inspect the affected wheelset.

When train 32N traversed the Salem, Ohio, HBD at MP 49.81, it triggered an alert at the Wayside Help Desk based on a single bearing temperature of 103°F above ambient with a Kt value of 5.8. When interviewed by the NTSB, the analyst on duty said that he did not see the alert from that HBD because he was working to resolve other, higher-priority alerts. When asked what he would have done if he had seen the Salem HBD alert in real time, he said that he would have monitored train 32N for alerts from subsequent HBDs in accordance with NS protocols.

⁶⁷ The algorithm communicates the significance of a bearing's temperature as a pair of K values—statistical indicators of how one measurement varies relative to a population. A Kt value indicates variation between a bearing and other bearings on the same side of the train; a Ke value indicates variation between a bearing and other bearings on a single piece of equipment.

⁶⁸ Operating rules effective at the time of the derailment were documented in *NS Operating Rules*, effective January 1, 2019.

At the NTSB's Investigative Hearing, the NS Assistant Vice President of Signals and Communications testified that NS based its criteria for hot bearing alerts and alarms on AAR standards and has refined the system over its years in service.⁶⁹ He also stated that under the alert procedures, non-critical alerts require monitoring rather than an immediate stop-and-inspect. He stated that this reflects the reality that most alerts do not require a prompt reaction, and many alerts do not develop into future issues.⁷⁰

1.5.3.2 Acoustic Bearing Detectors

In addition to HBDs, NS uses ABDs. ABDs are less common across the US rail network than HBDs; at the time of the derailment, NS had 5, and the Class I railroads had a total of 61. According to information provided by NS, its ABDs produced 3797 alerts between May 2013 and July 2023, and these alerts resulted in 2993 wheelset replacements handled by NS.

The last time the hopper car traversed an ABD was on October 12, 2022. The ABD returned a fault code of "noisy," one of several fault code prefixes that indicate the data returned by the ABD may not be reliable.⁷¹

1.5.4 Industry-Wide Use of Wayside Bearing Defect Detection

After the East Palestine derailment, the NTSB contacted all six Class I railroads and asked for information about how they use wayside bearing defect detection systems, including how they set alarm parameters, and planned changes. The results, provided between October 2023 and December 2023, are summarized in table 7.

⁶⁹ (a) NTSB Investigative Hearing Transcript, Day 2, pp. 211-12. (b) The AAR has a definition of a hot bearing, as discussed in section 1.5.4. The AAR also has recommended practices for trend analysis.

⁷⁰ NTSB Investigative Hearing Transcript, Day 2, pp. 212-13.

⁷¹ Noisy, FBS (flanging, braking, slamming), shrk (shriek), and clpd (clipped) prefixes are indicative of non-bearing faults, errors, or other external inputs that may diminish the reliability of the information gathered by the ABD. These prefixes typically suggest that there is an error with the reading, not a bearing-related issue.

Table 7. Summary of wayside detector survey results.

Subject	Railroad #1	NS	Railroad #3	Railroad #4	Railroad #5	Railroad #6
Average HBD spacing before 2/2/2023	16.2 miles	13.9 miles	19.9 (key routes)	17.3 miles	12.7 miles	15-25 miles
Average HBD spacing in autumn 2023	14.9 miles	13.0 miles	19.9 (key routes)	17.3 miles	12.7 miles	15-25 miles
Plans to install more HBDs	Possibly	Possibly	Yes	Yes, to average 15 miles	Possibly	Yes, to average 20 miles on key routes with ABDs
Individual bearing alarm parameters before 2/2/2023	170°F above ambient	Critical 200°F above ambient; non-critical between 170°F and 200°F above ambient [†]	170°F above ambient	190°F above ambient	165°F on core routes; 136°F on non-core routes	180°F above ambient
Bearing differential alarm parameters before 2/2/2023	Not used	115°F	150°F	117°F	95°F on core routes; 69°F on non-core routes	150°F
Testing and inspection intervals	Every 15 days	Every 30 days	Monthly	Every 56 days	Monthly	Monthly
Calibration intervals	Every 30 days	Every 180 days	Every 6 months	Semi-annual	Twice a year	Every 6 months
Number of ABDs before 2/2/2023	11	5	26	7	7	5
Number of ABDs in autumn 2023	12	21	26	7	8	11
Plans to install more ABDs	Yes, 2 additional	Yes, 1 additional	Under review	No	Yes, 7 additional	Yes, 4 additional

*A *key route* is a route that carries a high yearly volume of hazardous materials as defined in AAR Circular OT-55.

[†]After the East Palestine derailment, NS eliminated the “warm bearing” alarm and set its critical alarm threshold at 170°F above ambient.

The AAR defines “overheated” bearings in Rule 36, Section 11 of its Field Manual (AAR 2023). Under this definition, a bearing is overheated if one of the following conditions is met:

- The surface of the bearing cup reaches an absolute temperature of 200°F as measured by an AAR-approved device;

- A wayside HBD measures a temperature at least 170°F above ambient; or
- A wayside HBD measures a temperature at least 95°F above the temperature of the mate bearing on the same wheelset.

If the measurement comes from an HBD, the suspect bearing must be manually checked with a different instrument to confirm that it is significantly hotter than the next hottest bearing on the same side of the equipment. This is intended to ensure that the correct bearing has been identified.

At the NTSB's Investigative Hearing, the AAR Senior Vice President of Safety and Operations testified that AAR overheated bearing definitions are based on billing thresholds that govern when a railroad can take a railcar out of service for repairs.⁷² He also stated that individual railroads' thresholds for alerts and alarms are a balance between removing unsafe bearings from service and avoiding unnecessary stops that would reduce the effectiveness of the rail system. Railroads' choice of thresholds is normally made based on their experience with negotiating that balance.⁷³

1.5.5 Other Bearing Defect Detection Technologies

The NTSB has identified bearing defect detection technologies not yet in widespread use, such non-wayside, railcar-mounted systems designed to monitor bearing health by measuring vibrations. These include a railcar-mounted system under development at the University Transportation Center for Railway Safety that underwent testing in 2015 (Tarawneh, Montalvo, and Wilson 2021).⁷⁴ A related system that also measures impact loads to monitor track and wheel conditions along with bearing health is undergoing field testing on short-line railroads (Pams et al. 2024).

⁷² (a) NTSB Investigative Hearing Transcript, Day 2, pp. 215-16. (b) Responsibility for paying for railcar repairs is divided by contract between railroads and railcar owners or lessors. In general, a railcar defect that clearly places a railcar out of service, such as an overheated bearing that meets the AAR definition, is billable to the railcar owner or lessor.

⁷³ NTSB Investigative Hearing Transcript, Day 2, p. 215-16.

⁷⁴ The director of the University Transportation Center for Railway Safety at the University of Texas Rio Grande Valley, who was an author of the cited article, testified at the NTSB's Investigative Hearing about this family of technologies. See NTSB Investigative Hearing Transcript Day 2, pp. 235-36.

1.6 Hopper car GPLX75465

1.6.1 Manufacture, Ownership, and Movement History

GPLX75465 was a covered hopper railcar owned by the GATX Corporation and leased to Braskem America, Inc. It was manufactured in 1997 by Trinity Industries and purchased by GATX the same year.

The manufacturer of the bearings installed on the hopper car recommends moving equipment one railcar length every 6 months to distribute lubricant over bearing surfaces (Timken 2016). The NTSB reviewed 10 years of car location messaging (CLM) data to map the movement history of the hopper car. Movement is recorded by the CLM system only when a railcar passes a reader on a mainline, meaning that CLM records typically do not include movement within yards. CLM records showed that the hopper car remained in LaPorte, Texas, and did not pass a mainline reader for two periods exceeding 6 months: 565 days in 2017–2018 and 206 days in 2018–2019. Additional records from the yard in LaPorte where the hopper car was located indicated that it was moved within the yard during these periods; the longest period between movements was about 4 months.

Meteorological records reviewed by the NTSB showed that while the tank car was in LaPorte, Hurricane Harvey made landfall in southeast Texas and inflicted heavy rain over late August and early September 2017, resulting in widespread flooding. The weather reporting station at Houston Hobby Airport, about 14 miles from the LaPorte railyard, recorded 37 inches of rainfall from Hurricane Harvey.

CLM records also indicate that the hopper car was in Baltimore, Maryland, from June 1, 2016, until August 7, 2016. The weather reporting station at Baltimore/Washington International Thurgood Marshall Airport recorded severe weather during this period, including thunderstorms in June and July.

Timken states in its Guidelines for Bearings in Service, “Lubricant containing water is destructive to roller bearings, causing rapid wear. Take all possible precautions to prevent water from entering the bearing assembly. If the equipment is submerged in water deep enough that water could have entered the bearings, remove the bearing assemblies from the axles and send them to Timken for reconditioning” (Timken 2016).

Rule 36 of AAR’s Field Manual of the Interchange Rules states there is “cause for attention, at any time, roller bearings are partially or fully submerged” and that roller bearings submerged in a flood must be replaced (AAR 2023).

1.6.2 Bearing Examination

On February 4, 2023, the NTSB located the detached lead wheelset of the hopper car at the east end of the derailment pileup and near the hopper car itself. The hopper car was still smoldering, and the wheelset had been exposed to fire. The R1 bearing was still attached to the wheelset, but the L1 bearing and journal were missing, and the end of axle 1 was broken.⁷⁵ Later that day, the NTSB located components of the L1 bearing and journal from this wheelset west of the pileup and south of main track 1.⁷⁶ (See figure 15 and figure 16.) On February 5, after photographing the L1 bearing and journal in their as-found condition, the NTSB recovered the separated axle journal and several bearing components, including the outer seal, outer cone, bearing cup, inner cone, and inner seal, along with portions of cages and some rollers. Several rollers, the backing ring, and one inner seal wear ring were not found. (See figure 17 for a diagram of a disassembled bearing.) Note that there are inner and outer versions of several components.

⁷⁵ In a roller bearing, also called a journal bearing, one end of the axle is pressed into the bearing assembly. The part of the axle that sits inside the bearing itself is called the *bearing journal*.

⁷⁶ The NTSB matched the wheelset and bearing to the accident railcar using component identification numbers.



Figure 15. L1 journal as found on the scene.



Figure 16. Other L1 bearing components post recovery.

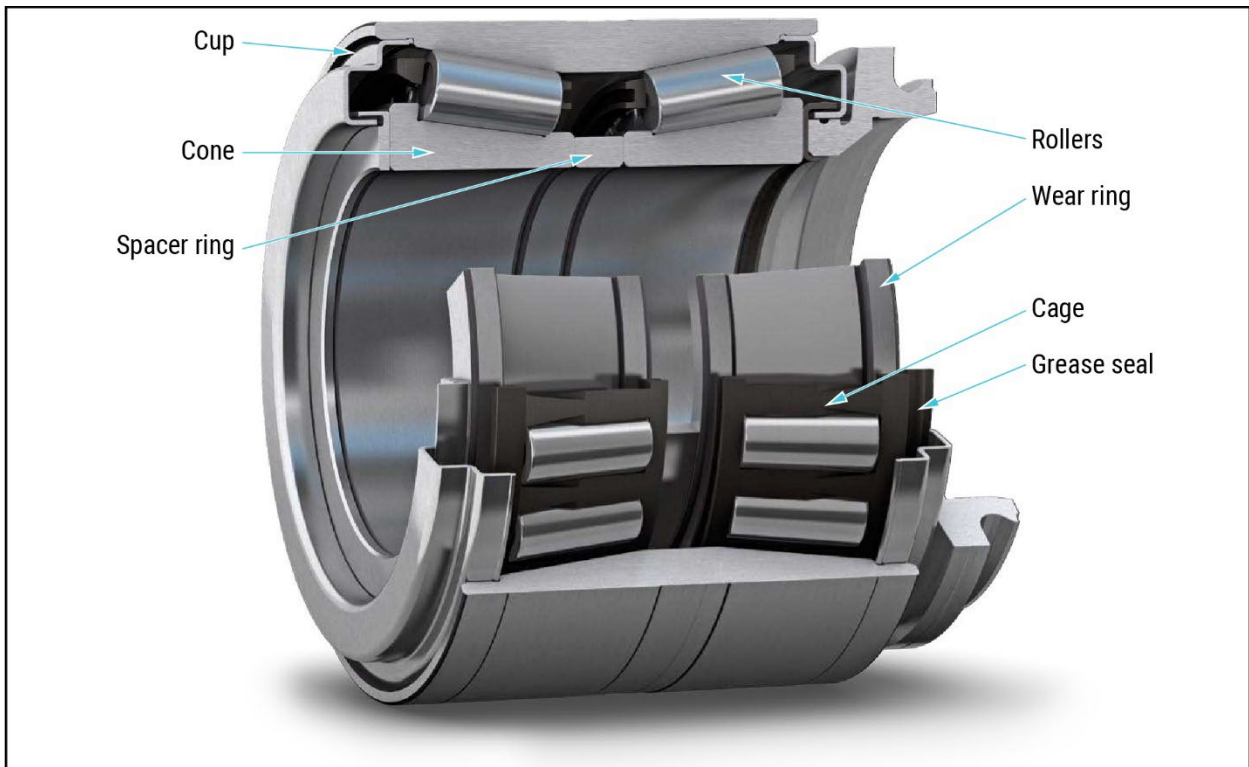


Figure 17. Diagram of a bearing with the journal removed. (Courtesy of SKF Group.)

An NTSB contractor disassembled and documented these components in the presence of the NTSB and party members on April 11, 2023. Markings on the components indicated that the bearing had been reconditioned in June 2011.⁷⁷ The L1 bearing's polymer grease seals were missing, and its steel components had sustained extensive damage as shown in figure 18 and figure 19, including:

- Melting: a change in state from a solid to a liquid. In failure analysis of metallic components, melting is typically preceded by softening and plastic deformation.
- Galling: a form of severe adhesive wear that occurs when metallic surfaces are in sliding contact. Galling can transfer material between these surfaces.
- Rub damage: a form of mechanical damage caused by two surfaces sliding against each other.
- Plastic deformation: a permanent change in the shape of a metallic component resulting from applied or internal forces.

⁷⁷ Bearings used in rail applications are commonly *reconditioned*—that is, disassembled, cleaned, inspected, repaired as needed, and reassembled—several times to extend their useful life.

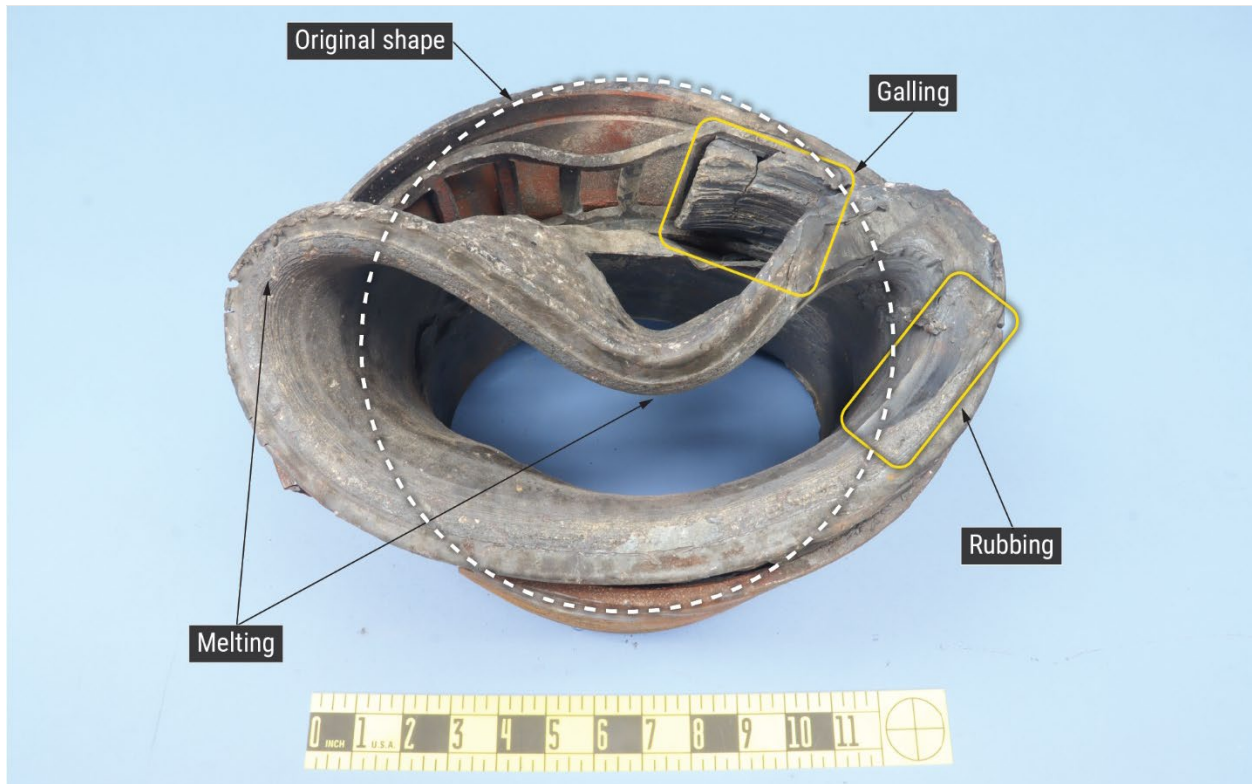


Figure 18. Recovered bearing cup and other components.

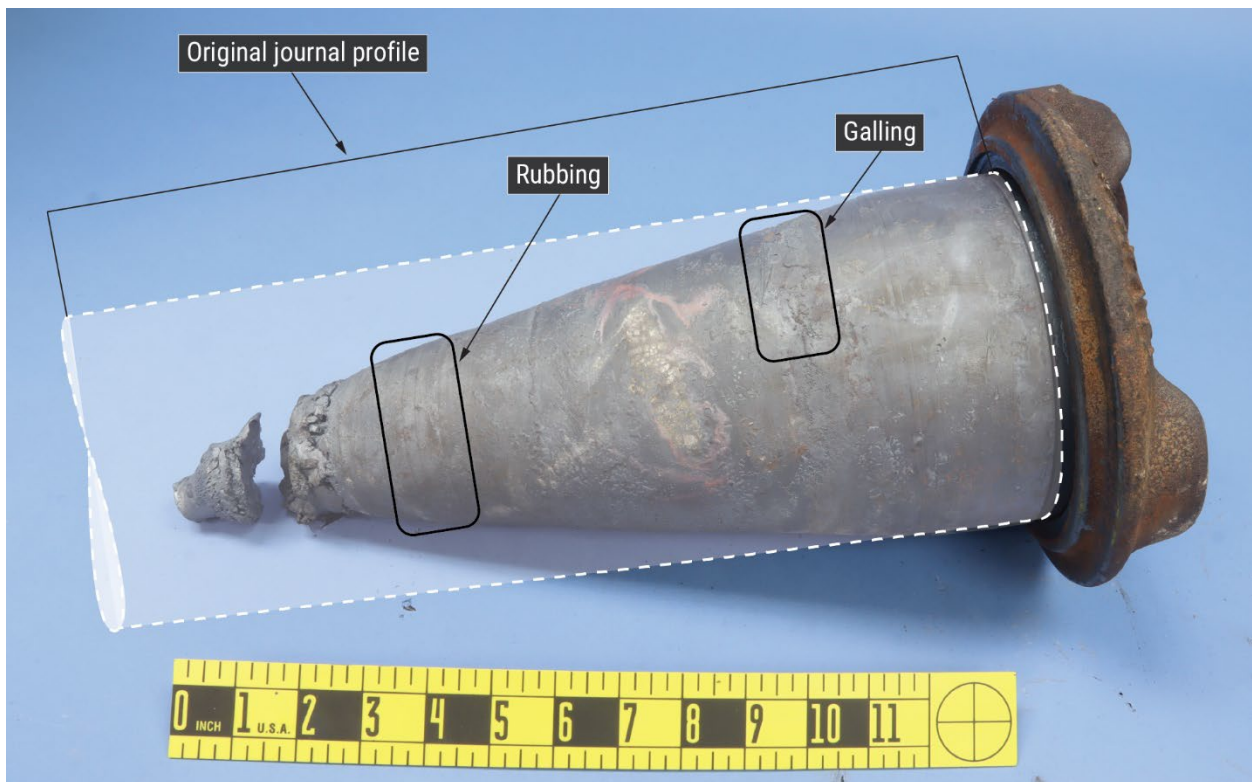


Figure 19. Recovered bearing journal.

1.7 Accident Tank Cars

1.7.1 Summary of Derailed Equipment

A total of 38 railcars derailed in East Palestine, including 27 tank cars. The derailed tank cars included four design specifications: DOT-105 (6 tank cars), DOT-111 (16 tank cars), DOT-117 (3 tank cars), and AAR-211 (2 tank cars).

The DOT-105 specification comprises a family of pressure tank cars whose subtype requirements are established at 49 *CFR* 179.101-1. The DOT-105 tank cars derailed in East Palestine were specification DOT-105J300W, meaning that they were jacketed and had a design bursting pressure of 750 psig and a test pressure of 300 psig.⁷⁸ They had a minimum head and shell plate thickness of 0.5625 inches of normalized steel, which was covered with a thermal protection system, and they lacked a bottom outlet or bottom washout. Each tank car was equipped with a single PRD among the top fittings, and within a protective housing, and with 0.5-inch-thick full-height headshields to protect the tank heads from impacts. Regulations at 49 *CFR* 179.16 require that tank head protection systems (head shields) be capable of sustaining, without loss of lading, coupler impacts to tank head at relative speeds of 18 mph.

The DOT-111 is one of several non-pressure tank car specifications established at 49 *CFR* 179 Subpart D. In general, DOT-111 tank cars may have features such as bottom outlet valves (BOVs) and hinged-and-bolted manways not found on DOT-105 tank cars. The specification itself does not require protective measures such as head shields or reclosing PRDs, though DOT-111 tank cars may be so equipped to qualify for certain kinds of hazardous materials service or to improve survivability. The DOT-111 tank cars that derailed in East Palestine were variously equipped with full-height head shields, half-height head shields, or no head shields. The 2015 Fixing America's Surface Transportation Act (FAST Act) established a phase-out schedule to remove DOT-111 and similar tank cars from flammable liquids service (Public Law

⁷⁸ (a) *Design bursting pressure* is the pressure at which a tank car will theoretically fail based on its physical properties. (b) *Test pressure* is the pressure at which a tank car is tested after its construction.

(PL) 114-94).⁷⁹ At the end of this phase out, by May 1, 2029, tank cars transporting flammable liquids must meet the newer DOT-117 specification.⁸⁰

The DOT-117 specification, established at 49 *CFR* 179.202, is a non-pressure tank car intended to offer improved survivability over the DOT-111 in derailments and fire conditions. The specification requires a 0.5625-inch-thick shell, full-height head shields, a jacket and thermal protection system, top fittings protection, and a BOV operating mechanism designed to prevent releases in derailment scenarios. DOT-117 tank cars must meet the same thermal survivability performance requirements as pressure tank cars.

The AAR-211 is an industry (non-regulatory) specification for a non-pressure tank car similar to the DOT-111. Unlike the DOT-111, the AAR-211 does not require a complete post-weld heat treatment of the tank material, does not require the same examination of welded joints if constructed of carbon or alloy steel, and allows additional industry-specific fittings (AAR 2022a).

1.7.2 Summary of Breaching Damage

Of the 27 derailed tank cars, 11 were carrying hazardous materials and 16 were carrying non-hazardous materials.⁸¹ On February 22, 2023, the NTSB examined the derailed hazardous materials railcars, eight of which released lading, to identify the primary sources of release. The examination results for the eight tank cars that released lading are summarized in table 8. The VCM tank cars lost lading through PRD activity and the vent and burn. The other hazardous materials tank cars lost lading mainly through mechanical damage—punctures or cracks in the tank heads.

⁷⁹ The NTSB has investigated numerous hazardous materials releases involving DOT-111 tank cars and made safety recommendations relevant to their removal from flammable liquids service. The subject is discussed in detail in section 2.4.2.

⁸⁰ The requirement that tank cars in flammable liquids service meet the DOT-117 specification means that two tank cars defined by industry specifications, the AAR-211 and CPC-1232, are also being disqualified from transporting flammable liquids. A CPC-1232 is a DOT-111 tank car built to additional industry standards and including specific protective features, such head shields and a PRD. The CPC-1232 standard is specifically referenced in the phase-out schedule, and the AAR-211 is relatively rare in flammable liquids service.

⁸¹ For a detailed account of the hazardous materials in the derailed tank cars, see section 1.8.

Table 8. Summary of breaching damage to hazardous materials tank cars.

Line Number	Tank Car	Specification	Commodity	Amount Released	Primary Source of Release
28	TILX402025	DOT-105	VCM	Entire load	Vent and burn
29	OCPX80235	DOT-105	VCM	Entire load	PRD release, vent and burn
30	OCPX80179	DOT-105	VCM	Entire load	PRD release, vent and burn
31	GATX95098	DOT-105	VCM	Entire load	PRD release, vent and burn
36	SHPX211226	DOT-111	Ethylene glycol monobutyl ether	Entire load	Tank head crack, BOV fully open
38	DOWX73168	DOT-111	2-ethylhexyl acrylate	Partial load	Tank head cracks, tank head puncture
50	UTLX205907	DOT-111	Butyl acrylates	Entire load	Tank head punctures, manway gasket burned away
55	OCPX80370	DOT-105	VCM	Entire load	PRD release, vent and burn

Figure 16 shows an example of tank head punctures sustained by a DOT-111 tank car, UTLX205907, which was constructed of non-normalized steel (which is less damage tolerant than normalized steel) and not equipped with a head shield.



Figure 20. Leading A-end head punctures on tank car UTLX205907.

Of the 16 derailed tank cars that were carrying non-hazardous materials, 6 released lading. Investigators identified the primary sources of released lading based on a combination of SPSI observations, NTSB observations, and reviews of photographs taken on the scene. The primary sources of released lading for these six tank cars are summarized in

table 9.

Table 9. Summary of breaching damage to non-hazardous materials tank cars.

Line Number	Tank Car	Specification	Commodity	Amount Released	Primary Source of Release
34	RACX51435	DOT-111	Propylene glycol	Entire load	Head puncture
41	UTLX100055	DOT-111	Petroleum lubricating oil	Entire load	Manway cover missing, top fittings sheared off, shell puncture
42	XOMX110664	AAR-211	Petroleum lubricating oil	Most of load	Unknown, reported by SPSI
44	UTLX671310	DOT-111	Petroleum lubricating oil	Partial load	Top fittings leaking and on fire
45	CERX30072	DOT-111	Polypropyl glycol	Entire load	Head puncture
47	NATX231335	DOT-111	Diethylene glycol	Entire load	Shell puncture

All five DOT-105 specification tank cars that lost VCM lading did so through PRD operation or the subsequent vent and burn procedure. Most of the DOT-111 and AAR-211 specification tank cars (both hazardous and non-hazardous materials tank cars) that lost lading sustained mechanical breaches during the derailment itself. The three derailed DOT-117 tank cars were transporting non-hazardous materials, and none were breached during the derailment or emergency response. Based on these initial examinations and observations, the NTSB focused subsequent investigative activity on the specific VCM tank cars involved in the derailment, including their certification and fittings.

1.7.3 Tank Car Certification

Under 49 *CFR* 179.5, a tank car (or a series of tank cars sharing a single design) must have a certificate of construction before entering service. The certificate of construction certifies that the tank, equipment, and car fully conform to the requirements of their specification.

Certificates of construction are contingent on AAR approval. Under 49 *CFR* 179.3, applications for approval of designs, materials of construction, conversion, or alteration of tank car tanks, complete with detailed prints, must be submitted to the AAR executive director of tank car safety for consideration by the AAR Tank Car Committee or any other appropriate committee. The applications for approval are submitted to the AAR using an application for a certificate of construction (AAR Form 4-2, or an addendum on Form R-1). According to 49 *CFR* 179.3, the committee approves applications when, in its opinion, such tanks or equipment comply with the requirements of applicable hazardous materials

regulations. In practice, applications are reviewed by “independent third-party entities” whose requirements the AAR establishes in section M-1002 of its Manual of Standards and Recommended Practices (MSRP) (AAR 2014).

Under 49 *CFR* 173.31, no person may offer a hazardous material for transportation in a tank car unless that tank car meets applicable specification and packaging requirements. Tank cars and appurtenances may be used for the transportation of any commodity for which they are authorized in federal hazardous materials regulations and as specified on the certificate of construction.⁸² The design and materials for fabrication, alteration, conversion, or welded repairs must be approved by the AAR in accordance with the Manual of Standards and Specifications for Tank Cars (M-1002). The design and materials of all valves and closures on tank cars must comply with Appendix A of M-1002 and be approved by the AAR Tank Car Committee.

The applicant for an AAR certificate of construction must certify that the tank car and its service equipment are compatible with the specified lading.⁸³ Upon reviewing the application for approval and certificate of construction, the AAR Tank Car Committee is then responsible for ensuring that all specification requirements are met. The tank car builder certifies the tank cars conform to the approved description and all applicable DOT and AAR requirements before the tank car is placed into hazardous materials service. Specification M-1002 further states that the revision or substitution for any valve or fitting, except substitution of equivalent kind approved on the certificate of construction, constitutes an alteration and must also be approved before use.

The design, materials, and flow capacity ratings of PRDs used on tank cars must also be approved by the AAR Tank Car Committee. In seeking approval of the Tank Car Committee for the PRD, the applicant—usually the PRD manufacturer—must file AAR Form 4-3, providing specifications and drawings and indicating the commodity for which the device is intended. AAR standards in Appendix A of the AAR Manual of Standards for Tank Cars also require determination of PRD flow

⁸² Under 49 *CFR* 178.320, *appurtenance* means any attachment to a cargo tank that has no lading retention or containment function and provides no structural support to the cargo tank. Common appurtenances include manway covers, ladders, and fasteners.

⁸³ Changing a tank car’s specified lading may require recertification depending on the exact change and whether the tank car needs to be retrofitted to transport the new lading.

capacity using either steam, air, natural gas, or the lading for which the PRD is intended (AAR 2014).

1.7.4 VCM Tank Cars

The five derailed VCM tank cars were all DOT-105s but entered service under four different certificates of construction, were equipped with different fittings, and were owned by three different companies.

Three tank cars were owned and maintained by Oxy Vinyls: OCPX80235, OCPX80179, and OCPX80370. All three were built under certificates of construction following AAR approval. For two tank cars, OCPX80235 and OCPX80179, the applicable certificate of construction specified the initial commodity as “vinyl chloride.” For OCPX80370, the initial commodity was “vinyl chloride, inhibited, and products authorized in DOT Part 173 [sic] for which there are no special commodity requirements and nonregulated commodities compatible with this class of car.”⁸⁴

One tank car (GATX95098) was leased under a full-service agreement between GATX Corporation (the lessor) and Occidental Chemical Corporation (the lessee). Under this lease, the tank car was maintained by GATX and bore a GATX reporting mark.

GATX95098 was built under a certificate of construction following AAR approval. The initial commodity for this tank car was listed on the certificate of construction as “propylene oxide and products authorized in DOT 173 [sic] for which there are no special commodity requirements and nonregulated commodities compatible with this class of car.”⁸⁵

The fifth tank car (TILX402025) was leased under a master railcar lease agreement between Trinity Industries Leasing Company (lessor) and Occidental Chemical Corporation (lessee). Under this lease, Trinity Rail (a subsidiary of Trinity

⁸⁴ Special requirements for compressed gases transported in tank cars are found in 49 *CFR* 173.314, which was last amended on December 21, 1990. See 55 *Federal Register* (Fed. Reg.) 52665.

⁸⁵ (a) Tank car GATX95098 was built in 1992. (b) Special requirements for compressed gases transported in tank cars and having a primary or secondary Division 2.1 (flammable gas) hazard are found in 49 *CFR* 173.314(j). VCM is a Division 2.1 flammable gas. Additionally, under 49 *CFR* Part 172 Subpart B, VCM is subject to Special Provision B44 as described in 49 *CFR* 172.102. Special Provision B44 requires that all parts of valves and safety relief devices in contact with lading must be made of a material which will not cause formation of acetylides.

Industries) was responsible for maintaining and repairing the tank car, other than running repairs as defined by the Interchange Rules of the AAR. The lessee was responsible for replacement of lost or broken removable parts (such as dome covers, outlet caps, gates, hatches, and gaskets). The lessor was responsible for the maintenance and replacement of PRDs, angle valves, check valves, and other service equipment.

TILX402025 was built under a certificate of construction following AAR approval. The initial commodity for this tank car was listed on the certificate of construction as “vinyl chloride, inhibited.” The top fittings specifications referenced in the certificate of construction included a specific PRD with a start-to-discharge pressure of 247.5 psig and aluminum-coated spring.⁸⁶

After the derailment, the FRA inspected the five VCM tank cars, reviewed certificates of construction, and issued inspection reports to Oxy Vinyls, Trinity Rail, and GATX on August 16 and 21, 2023. The FRA reports noted that none of the five VCM tank cars matched its design approval.

More specifically, discrepancies reported by the FRA included:

- The certificate of construction for OCPX80235 specified a Midland Manufacturing model A-34247 PRD with a start-to-discharge pressure of 247.5 psig. According to Oxy Vinyls’ records, the PRD on OCPX80235 was changed to an A-37247 in 2021.
- The certificate of construction for GATX95098 specified a Midland Manufacturing model A-34225 PRD with a start-to-discharge pressure of 225 psig. In 1996, the PRD was changed to a Midland Manufacturing model A-34247 with a start-to-discharge pressure of 247.5 psig.
- GATX records indicated the original angle valves on GATX95098 were Neles-Jamesbury model AZFRA, 2236-TT, with unknown serial numbers and manufacturing dates. An AAR Form R-1 (Report of Tank Repairs, Alteration, or Conversion) dated April 4, 2007, indicated that these valves were replaced with Midland A-720 angle valves.

⁸⁶ The Oxy Vinyls SDS for VCM states that VCM is incompatible with aluminum and aluminum alloys and can react exothermically with these materials. See section 1.8.1.1 for more information about VCM hazards.

- The revision level for drawings applicable to TILX402025 did not match the revision level approved on the original certificate of construction.
- For OCPX80179 and OCPX80370, the FRA noted missing or incorrect information on the AAR Form 4-2, such as incorrect drawing revision levels and drawings with revision levels dated after the original approval.

1.7.5 Postderailment Tank Car Examinations and Tests

1.7.5.1 Tank Car Examinations

The NTSB's February 22, 2023, examination of the five derailed VCM tank cars identified no mechanical breaches other than those intentionally created during the vent and burn. The examination did not identify dents, cracks, gouges, or scores in the tank shells, and there were no signs of significant damage near weld zones. The NTSB also identified no evidence of shell bulging or stretching, common signs of thermal damage.

During these examinations, the NTSB found aluminum valve handles on all five VCM tank cars. The NTSB also found that the steel protective housing covers installed on two VCM tank cars (TILX402025 and OCPX80370) had remained attached to their respective housings. However, the aluminum protective housing covers installed on three VCM tank cars (OCPX80235, OCPX80179, and GATX95098) had been destroyed or were missing from their housings. (See figure 21 for an example.) The NTSB also observed metallic debris in the PRD top guides and protective housings of these three VCM tank cars.⁸⁷ (See figure 22.) Midland Manufacturing, the manufacturer of these three PRDs, notes in its PRD installation, maintenance, and operation manual that, "The area of discharge through the top guide must be unobstructed by foreign matter that would hinder free flow of discharging fluid" (Midland Manufacturing 2021).

⁸⁷ OCPX80370, which had a steel cover, had aluminum valve hand wheels on its top fittings, which were not found intact during postderailment examinations. However, the NTSB did not observe metallic debris in this tank car's PRD outlet guide.



Figure 21. Tank car OCPX80235's protective housing with the aluminum cover missing.



Figure 22. Metallic debris in the PRDs of tank cars equipped with aluminum protective housing covers.

Investigators collected samples of metallic debris and sent them to the NTSB Materials Laboratory in Washington, DC, for examination. After NS contractors removed pressure plates from all five VCM tank cars, the NTSB recovered the PRDs for bench testing at the Trinity Rail Maintenance Services Saginaw Plant in Saginaw,

Texas, on March 15–16, 2023.⁸⁸ During these tests, the NTSB collected two additional samples of metallic debris and sent them to the NTSB Materials Laboratory for analysis alongside the samples collected on the scene. Sample collection and location information is summarized in table 10. The NTSB Materials Laboratory determined that the samples were all more than 50% aluminum by weight.

Table 10. Metallic debris sample information.

Tank Car	Location of Sample Collection	Location of Sample
OCPX80235	On scene in East Palestine	PRD
OCPX80179	On scene in East Palestine	Protective housing
GATX95098	On scene in East Palestine	Top fittings protective housing
OCPX80235	Bench test Saginaw, Texas	PRD
GATX95098	Bench test Saginaw, Texas	Protective housing

1.7.5.2 PRD Bench Tests and Examinations

On March 15–16, 2023, the NTSB and Trinity Industries examined and bench tested the recovered PRDs. Figure 23 provides a diagram and photograph of a new Midland PRD comparable to the ones recovered from the VCM tank cars.

⁸⁸ Trinity Rail Maintenance Services is a subsidiary of Trinity Industries.

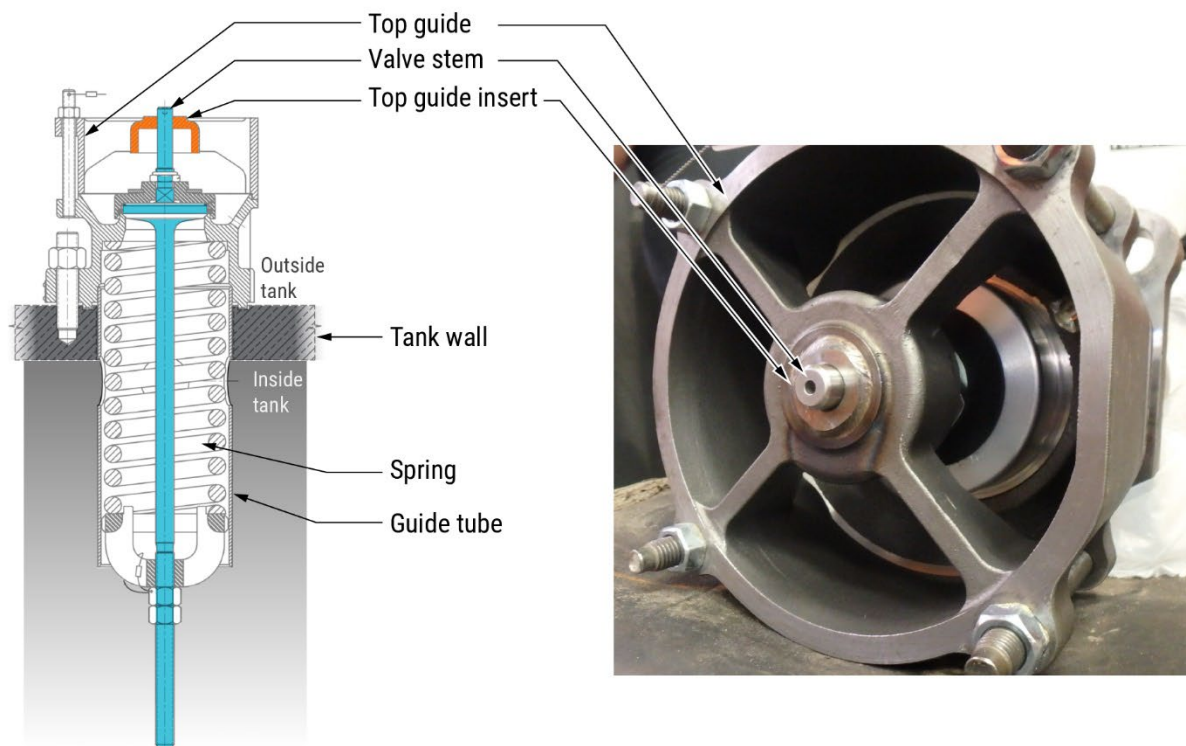


Figure 23. PRD diagram (left) and top-down view of exemplar (right). (Diagram courtesy of Midland Manufacturing with NTSB edits.)

The TILX402025 PRD top guide throat contained loose fragments of metallic debris. During testing, the PRD began to leak (release material without actuating) at 33.4 psig. According to its part specification, the spring was originally coated in aluminum. After bead blasting to remove carbon and soot, visual examination of the spring revealed that most of its aluminum coating was missing. The PRD did not contain any foreign matter obstructing its internal components.

The OCPX80235 PRD top guide discharge port contained about 0.56 pounds of melted and re-solidified metallic debris, mostly aluminum. The interior of the protective housing and interior surface of the pressure plate were corroded. When tested, the PRD began to leak or discharge at 122 psig. After replacement of the PRD's O-rings, the PRD held pressure up to 150 psig without leaking or discharging; investigators did not further increase the pressure for safety reasons. The interior of the protective housing and interior surface of the pressure plate were corroded. The PRD's internal parts were also covered in corrosion and a thin layer of carbon or soot. The PRD did not contain any foreign matter obstructing its internal components.

The OCPX80179 PRD top guide contained flakes of metallic debris, and solidified masses of melted aluminum were present around other valves fitted to the

pressure plate. The interior of the protective housing and interior surface of the pressure plate were corroded. When bench tested, the PRD began to leak at 49.2 psig and to discharge at 149.7 psig. The PRD valve stem was stuck to the top guide insert bushing and had to be destructively separated with torch cutting, hammering, and lubrication for further examination. The PRD spring had been permanently compressed such that it could not rebound to the minimum height specification for a new PRD. The PRD did not contain any foreign matter obstructing its internal components.

The GATX95098 PRD body had fused to the pressure plate and significant force was required to separate them. The top lock nut and retainer were stuck to the valve stem. The top guide discharge structure and top guide bushing had burned away from the PRD, and material had been eroded from the threaded steel mounting studs. Its spring was deformed and bent about 30° from its original shape. The PRD was too damaged to be bench tested under pressure or further dismantled.

The OCPX80370 PRD top guide was free of debris. The aluminum angle valve handwheels were missing, and the interior of the protective housing and interior surface of the pressure plate were corroded. When bench tested, the PRD did not leak or discharge at its rated state-to-discharge pressure of 247.5 psig and continued to hold pressure up to 275 psig. Investigators did not further increase the pressure for safety reasons. As with the PRD from OCPX80179, the PRD valve stem was stuck to the top guide insert bushing and had to be destructively separated with torch cutting, hammering, and lubrication for further examination. The top of the stainless steel valve stem was covered with rust.

After testing and disassembly, the PRD from OCPX80370 was shipped to the NTSB Materials Laboratory for further examination. When examined, the PRD exhibited thick layers of soot and reddish-brown burned deposits on its inner surfaces. Similar reddish-brown deposits were present in a band around the mating valve stem. These deposits persisted on the valve stem even after it was subjected to plastic bead blasting and the remainder of the valve stem appeared silver. The bottom of the band was about 0.75 inches from the valve stem end. The removal of other deposits left divots in the valve stem surface. The PRD did not contain any foreign matter obstructing its internal components.

1.8 Hazardous Materials

The derailed tank cars contained a total of six hazardous materials representing Class 3 flammable liquids, combustible liquids, and Division 2.1 flammable gases. Table 11 provides the regulatory definitions of these materials.

Table 11. Regulatory definitions of hazardous materials involved in the derailment.

Type of Material	CFR reference	Class	Defintion
Flammable liquid	173.120	3	A liquid with a flash point of not more than 140°F that does not meet a series of exceptions named in the regulation. Class 3 flammable liquids may be assigned to Packing Group I, II, or III based on their flash points and boiling points. Lower Packing Group numbers correlate to greater levels of hazard.
Combustible liquid	173.120(b)	N/A	A liquid with a flash point above 140°F and below 200°F. A flammable liquid with a flash point of 100°F or higher may be reclassified as a combustible liquid if it does not meet the definition of any other hazard class.
Flammable gas	173.115(a)	Class 2, Division 2.1	Any material which is a gas at 68°F or less and 14.7 pounds per square inch of pressure and is ignitable at 13% or lower concentration in air or has a flammable range in air of at least 12% regardless of the lower limit of flammability.*

* The *flammable range* is the difference between the minimum and maximum volume percentages of a material in air that forms a flammable mixture.

The specific hazardous materials involved in the derailment are listed in table 12 as described on their shipping waybills. Warnings and safety information associated with each hazardous material are discussed below.

Table 12. Summary of derailed hazardous materials.

Identification Number	Shipping Name	Hazard Class or Division	Packing Group	Notes	Released
UN1086	Vinyl chloride (stabilized)	2.1	N/A	Referred to as VCM in this report	Yes
NA1993	Combustible liquid, n.o.s.*	N/A	III	Ethylene glycol monobutyl ether, which is not specified by name in the DOT table	Yes
NA1993	Combustible liquid, n.o.s.	N/A	III	Ethylhexyl acrylate, which is not specified by name in the DOT table	Yes
UN1055	Isobutylene	2.1	N/A	Flammable liquified compressed gas	No
UN2348	Butyl acrylates (stabilized)	3	III	Flammable liquid	Yes
UN1114	Benzene (residue)	3	II	Flammable liquid	No

* *n.o.s.* means "not otherwise specified" and is used for substances not assigned a single technical name in the hazardous materials table at 49 CFR 172.101.

1.8.1 Vinyl Chloride, Stabilized (UN1086, Division 2.1)

On January 23–24, 2023, Oxy Vinyls loaded and shipped five tank cars with a total of 887,400 pounds of VCM at the Oxy Vinyls VCM plant in LaPorte, Texas. The shipment was destined for another Oxy Vinyls facility in Pedricktown, New Jersey. Oxy Vinyls' internal certificates of analysis for the VCM in these tank cars indicated the vinyl chloride was 99.99% pure by weight. Oxy Vinyls' specification calls for 99.98% purity.

1.8.1.1 VCM Hazard Information

Because VCM is a hazardous material, federal regulations require communication of hazard information through container marking or labeling, placarding, SDSs, and employee training.⁸⁹ Oxy Vinyls maintains an SDS for VCM, which was last revised on November 30, 2020, and was referenced by the incident command during the East Palestine emergency response on February 4, 2023. The SDS characterizes VCM as flammable, explosive in the presence of fire, and requiring stabilization (using either a polymerization inhibitor or purging to remove oxygen) to prevent dangerous polymerization.⁹⁰

The SDS notes that VCM is incompatible with oxidizing agents, oxides of nitrogen, metals, aluminum and aluminum alloys, copper, and metal alkyl complexes and alkali metals such as sodium, potassium, and their alloys. According to the SDS, reactions with these substances can be strongly exothermic. It also notes that VCM is "generally stable at normal temperatures and pressures" but that violent (and exothermic) polymerization may occur if VCM is not stabilized or stored correctly, and that if not properly stabilized, VCM may polymerize when exposed to air, sunlight, aluminum, oxidizing agents, or excessive heat.

The incident command at East Palestine also referred to The Chlorine Institute's Pamphlet 171, which discusses VCM polymerization and includes guidance specific to VCM as a tank car lading. According to Pamphlet 171, a pressure above 68 psig in an intact tank car "may indicate that VCM is polymerizing inside the tank car" (The Chlorine Institute 2018a). The pamphlet also recommends using an infrared

⁸⁹ Under Occupational Safety and Health Administration requirements at 29 *CFR* 1920.1200, a chemical manufacturer, importer, or employer must prepare an SDS based on the full range of available scientific literature and other evidence concerning potential hazards.

⁹⁰ Federal regulations at 49 *CFR* 171.8 define "stabilized" as "is in a condition that precludes uncontrolled reaction" and state that this may be achieved through chemical inhibition, removing dissolved oxygen and inerting air space in a package, temperature control, or other methods.

thermometer on the pressure plate or manway of the tank, and states that if the measurement is “above ambient temperature it may imply that VCM is polymerizing inside the tank car.” Finally, the pamphlet states, “If both pressure and temperature are above normal conditions, then a polymerization reaction is most likely occurring in the tank car. Appropriate action should be taken.” Pamphlet 171 does not name specific “appropriate actions” for polymerization, but it does note the importance of obtaining an accurate damage assessment to determine whether to move the tank car within the incident area, transfer the lading on site, or relocate the tank car to a suitable industry facility for unloading or controlled venting (The Chlorine Institute 2018a).

The 2020 ERG, a USDOT resource intended for use by first responders during the initial phase of a transportation incident involving hazardous materials, designates stabilized VCM with a “P,” signifying that it may polymerize explosively when heated or involved in a fire (PHMSA 2020). If a tank car carrying VCM is involved in a fire, the ERG recommends a 1-mile radius of evacuation.

FRA guidance on runaway reactions in tank cars, including polymerization of monomers, describes the principal hazard as overpressure leading to an explosion (FRA 1995). In a communication to the NTSB dated April 14, 2023, Oxy Vinyls also stated that “runaway polymerization reactions are highly exothermic and would be marked by a rapid, significant, and sustained increase in temperature and pressure.”

In the months following the derailment, the NTSB gathered additional information about the risk of VCM polymerization under the conditions present at East Palestine. On April 3, 2023, the NTSB met with a chemistry professor with VCM industry experience, including as an employee of a company related to Oxy Vinyls, and expertise on polymers and organic chemistry.⁹¹ He noted that VCM requires free radicals to initiate polymerization, and that a sustained reaction requires continuous introduction of free radicals; a small amount of free radicals in a tank car will not result in a sustained reaction.⁹² He further explained that VCM cannot undergo spontaneous thermally generated polymerization, in which the VCM is converted to polymer by thermal energy alone, because the decomposition temperature of the

⁹¹ This expert was a professor of chemistry at Indiana University and had previously worked for the Occidental Chemical Corporation, a company related to Oxy Vinyls, and was a paid consultant of Oxy Vinyls following the derailment. Oxy Vinyls recommended him as a technical expert before becoming a formal party to the investigation.

⁹² A *free radical* is an atom, molecule, or ion with at least one unpaired valence electron. Most free radicals are highly chemically reactive.

VCM (1,022°F) is higher than the temperature at which the polymer is destroyed (572°F).⁹³

At the NTSB's Investigative Hearing, the chemistry professor testified that the only condition under which VCM may polymerize is in the presence of a free radical initiator and that polymerization cannot occur without that initiator.⁹⁴ He also reviewed the Oxy Vinyls SDS for VCM and could not find scientific justification for the SDS's warnings regarding polymerization of stabilized VCM in the presence of oxygen, air, sunlight, heat, or aluminum. He referred specifically to an article stating that gaseous oxygen will not react with pure liquid VCM (Zilberman 1992). He also stated that temperatures of 180-185°F will have no effect on VCM.

Oxy Vinyls' vice president of health, environment, safety, and security also testified about the properties of stabilized VCM at the NTSB's Investigative Hearing. He stated that VCM can be stabilized by packaging it in a low-oxygen environment or through the addition of chemical inhibitors.⁹⁵ He testified that while some inhibitors can be lost through fire exposure, VCM stabilized through the removal of oxygen will remain stabilized when heated. He also stated that the SDS lists polymerization as a risk because the SDS covers a wide variety of scenarios, including manufacturing, industrial facilities, laboratories, storage, and transport in railcars, and it is intended to warn against polymerization if the VCM loses stabilization.

1.8.1.2 VCM Tank Car Lading

The VCM tank cars were loaded using an Oxy Vinyls standard operating procedure intended to stabilize the VCM for shipment by packaging it in a low-oxygen environment as required by Special Provision 21 of 49 *CFR* 172.102. The procedure outlined precautions, tank car inspections (pre- and post-loading), and safe practices for loading operations. These inspections included checking liquid and vapor valves and PRDs for leaks, examining connection threads, confirming oxygen concentration (less than 200 parts per million), and verifying the presences of appropriate and visible stenciling, placards, and security seals. Oxy Vinyls personnel noted no issues during inspections.

⁹³ The *decomposition temperature* is the temperature at which a substance chemically breaks down into other substances. For VCM, temperatures high enough to break carbon bonds and cause polymerization are too high to allow polyvinyl chloride (PVC) to exist.

⁹⁴ NTSB Investigative Hearing Transcript, Day 1, pp. 180-83.

⁹⁵ NTSB Investigative Hearing Transcript, Day 1, pp. 169-70.

Tank cars must be loaded within the outage limitations set by 49 CFR 173.24b(a) and by the stenciled load limits displayed on the tank car. According to the regulation, the minimum required outage is 1% of the total volume capacity of the tank for VCM shipped as a compressed liquefied gas.⁹⁶ In addition, under 49 CFR 179.13, each VCM tank car’s gross weight (the combined weight of the tank car and its lading) could not exceed 263,000 pounds. Oxy Vinyls personnel recorded the loading temperature and pressure for each tank car, as shown in table 13, which resulted in the lading volumes and weights shown in table 14.

Table 13. Loading temperatures and pressures for VCM tank cars.

Tank Car Number	Final Loading Pressure (psig)	Final Loading Temperature (°F)
TILX402025	49.48	59.03
OCPX80235	38.26	59.00
OCPX80179	35.15	58.93
GATX95098	32.76	59.13
OCPX80370	45.84	69.33

Table 14. Lading information for VCM tank cars.

Tank Car Number	Gross Weight. (lbs.)	Lading Weight (lbs.)	Lading Volume at Loading Temperature (gallons)	Tank Capacity (gallons)
TILX402025	261,200	178,300	23,223	25,170
OCPX80235	261,250	177,250	23,086	24,875
OCPX80179	261,100	177,600	23,132	24,899
GATX95098	261,350	178,150	23,203	25,740
OCPX80370	256,900	176,100	22,936	24,620

1.8.1.3 Postderailment Sampling

On February 16–17, 2023, the Oxy Vinyls logistics process supervisor collected a total of 12 samples of residues from the interiors of the VCM tank cars involved in the vent and burn to test for the presence of polymerized vinyl chloride (polyvinyl chloride, or PVC). The logistic process supervisor collected these samples as NS contractors removed pressure plate assemblies from the vinyl chloride tank cars. The samples were mostly collected from residue adhering to points on the underside of pressure plates or within tank nozzles. Most samples resembled black powder or ash.

⁹⁶ *Outage* refers to the tank space, sometimes called the “vapor space,” not occupied by lading.

The Oxy Vinyls logistics process supervisor delivered the 12 residue samples to the Oxy Vinyls Avon Lake, Ohio, Technical Center's PVC laboratory for analysis. Oxy Vinyls provided the NTSB with its analysis report on March 20, 2023. The analysis did not find PVC in any of the samples. Most of the samples' constituent elements were carbon, iron, and chlorine. Four samples, all collected from within or near the PRDs, contained 1-2% aluminum by weight.

1.8.2 Ethylene Glycol Monobutyl Ether (NA1993, Combustible Liquid)

On January 26, 2023, the Equistar Chemicals plant in Pasadena, Texas, loaded tank car SHPX211226 with 185,750 pounds of ethylene glycol monobutyl ether. The shipment was destined for Equistar Chemicals' Bayonne, New Jersey, facility.

According to the manufacturer's SDS, ethylene glycol monobutyl ether is flammable, toxic, odorous, explosive if vapors are concentrated, and may produce peroxides that will explode in response to heat or shock. Its flash point is 144°F. The ERG recommends a half-mile evacuation for tank car fires involving ethylene glycol monobutyl ether (PHMSA 2020).

1.8.3 Ethylhexyl Acrylate (NA1993, Combustible Liquid)

On January 27, 2023, the Union Carbide Corporation loaded tank car DOWX73168 with 205,900 pounds of ethylhexyl acrylate and shipped it from Union Carbide's Taft, Louisiana, plant. The shipment was destined for the Avery Dennison Corporation in Mill Hall, Pennsylvania.

The manufacturer's SDS notes that ethylhexyl acrylate is an irritant and a combustible liquid. Its flash point is 86°C (187°F).⁹⁷ The ERG recommends a half-mile evacuation for tank car fires involving ethylhexyl acrylate (PHMSA 2020).

1.8.4 Isobutylene (UN1055, Division 2.1)

On January 26, 2023, Lyondell Chemical Company loaded tank car NATX35844 with 155,642 pounds of isobutylene and shipped it from Pasadena,

⁹⁷ An SDS may use either Fahrenheit or Celsius. This report provides the original value and converts it into Fahrenheit when necessary.

Texas, destined for Synthomer Jefferson Hills LLC in Jefferson Hills, Pennsylvania. The isobutylene was described on the bill of lading as UN1055 isobutylene.

The manufacturer's SDS describes isobutylene as extremely flammable, colorless liquified compressed gas. Its flash point is listed as -76°C (-104°F). The ERG recommends a 1-mile evacuation for tank car fires involving isobutylene and directs the reader to BLEVE precautions (PHMSA 2020).

1.8.5 Butyl Acrylates (UN2348, Class 3)

On January 28, 2023, Arkema, Inc. loaded tank car UTLX205907 with 194,300 pounds of butyl acrylates and shipped it from Arkema's Pasadena, Texas, facility. The shipment was destined for another Arkema facility in Pottstown, Pennsylvania.

The manufacturer's SDS notes that butyl acrylates are irritants and harmful to aquatic life. The flash point is 102°F . The ERG recommends a half-mile evacuation for tank car fires involving butyl acrylates (PHMSA 2020).

1.8.6 Benzene Residue (UN1114, Class 3)

On January 25, 2023, SASOL Chemicals USA, LLC, shipped tank cars DPRX259013 and DPRX25867, having first unloaded their cargo of benzene. The tank cars contained an unknown amount of residue and were destined for PBF Holding in Delaware City, Delaware.

The manufacturer's SDS characterizes benzene as a highly flammable liquid and vapor, an irritant, and toxic to aquatic life. Its flash point is 12°F . The ERG recommends a half-mile evacuation for tank car fires involving benzene (PHMSA 2020).

1.9 Emergency Response

1.9.1 Incident Command Structure

The emergency response in East Palestine used the National Incident Management System (NIMS) doctrine developed by the Federal Emergency Management Agency (FEMA). Under this doctrine, a single incident command is responsible for the overall management of the incident. An incident commander or unified command conducts the command function, directing other functional areas to

meet whatever needs arise during the incident (FEMA 2017). Figure 24 illustrates the organization of a response with a single incident commander and general staff section chiefs for operations, planning, logistics, and finance and administration.

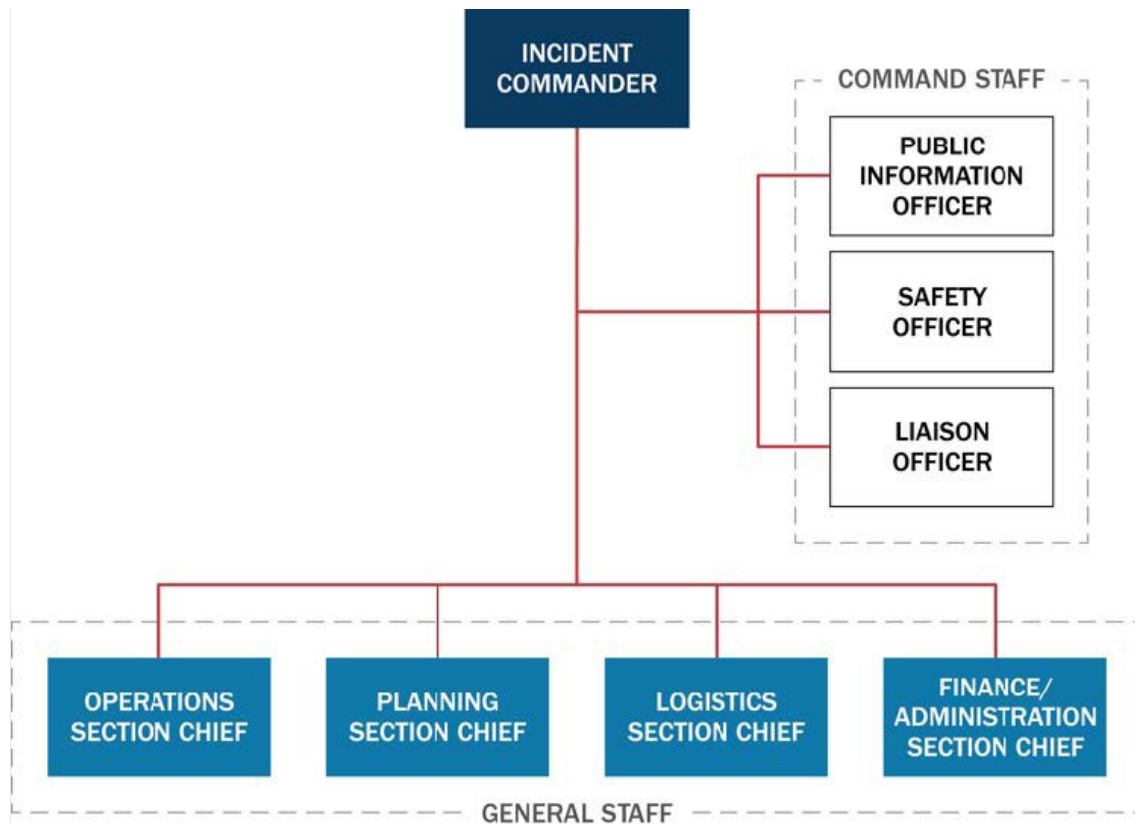


Figure 24. NIMS incident command structure. (Courtesy of FEMA.)

For incidents that do not involve multiple jurisdictions, a single incident commander performs the incident command function with the support of other involved agencies or organizations. The choice of an incident commander depends on the location of the incident:

When an incident occurs within a single jurisdiction and without jurisdictional or functional agency overlap, the appropriate authority designates a single Incident Commander who has overall incident management responsibility. (FEMA 2017)

The East Palestine derailment occurred within the emergency services jurisdiction of the municipal agencies of East Palestine, a civil municipality of Columbiana County. These agencies include the EPFD and EPPD. The EPFD is the principal emergency services agency responsible for responding to fire suppression, emergency rescue, and an initial response to hazardous materials incidents within East Palestine. The role

of incident commander was assumed by the most senior available EPFD firefighter: initially the EPFD deputy fire chief, and later the EPFD fire chief.

Based on the NTSB's review of incident action plans completed during the emergency response, agency and organization representatives liaising with the incident commander included personnel from the Environmental Protection Agency, CCEMA, the Village of East Palestine, and NS. The incident command staffed all four general staff sections, and the operations section included fire, EMS, and law branches.

1.9.2 Emergency Responder Interoperability

The 2019 National Emergency Communications Plan (NECP) published by the Cybersecurity and Infrastructure Security Agency (CISA) provides a roadmap to emergency communications interoperability at all levels of government. One goal set by the NECP is communications coordination under NIMS:

Public safety organizations use the National Incident Management System Incident Command System processes, methods, and structures across all disciplines, jurisdictions, and levels of government to standardize methods, practices, and actions during planned events and incident responses. As public safety organizations maintain, implement, upgrade, or replace existing communications capabilities, those capabilities should reflect an alignment with the National Incident Management System Incident Command System doctrine to ensure available fielded capabilities are sufficient to support primary, secondary, and backup services. (CISA 2019)

In support of this goal, interoperability channels have been designated and allocated by the federal government under regulations at 49 *CFR* Part 90, including very high frequency (commonly called VHF), ultra high frequency (commonly called UHF), 700MHz, and 800-MHz systems. Radio systems for emergency responders are subject to numerous regulations and standards governing their use and minimum interoperability requirements, including Federal Communications Commission regulations. For example, holding a Federal Communications Commission license as an emergency response agency fulfills a prerequisite Federal Communications Commission regulation allowing for the use of the national and state interoperability channels described above. Authorities having jurisdiction are ultimately responsible for ensuring interoperability through suitable equipment, protocols, and training of

personnel. CISA maintains a list of grant programs intended to support investment in emergency communications, including emergency responder interoperability.⁹⁸

The fundamentals of interoperability within the Incident Command System under NIMS are addressed in the IS-700.B training course, which is freely available through FEMA. The course specifies an hour of training on communications and information management, including the need for interoperable equipment and noting that:

Regardless of the communications hardware being used, standardized procedures, protocols, and formats are necessary to gather, collate, synthesize, and disseminate incident information. (FEMA 2020)

As discussed above in section 1.1.2, emergency responders at East Palestine reported issues with radio interoperability and consist and hazardous material information was disseminated during the response through a combination of emails, phone calls, radio communications, and paper copies.

1.9.3 The Chlorine Institute Chlorine Emergency Plan

In 1972, The Chlorine Institute launched the Chlorine Emergency Plan (CHLOREP) to provide transportation companies, emergency responders, and others with industry expertise on chlorine products such as VCM during incidents. As part of CHLOREP, The Chlorine Institute identifies capability requirements for emergency response contractors and regularly verifies that they meet these requirements. The highest level of capability under CHLOREP is Level 3, and as of the date of this report, there are three Level 3 contractors: SPSI, SRS, and United Professional Services, LTD.⁹⁹ As described in the "CHLOREP Contractor Verification Program Description," Level 3 contractors must be able to respond "to a chlorine leak from a small container ... or minor release from a tank car" and must have "special handling and field transfer capabilities for severely or potentially damaged bulk chlorine containers (i.e. cargo tanks and tank cars)" (The Chlorine Institute 2018b). The Chlorine Institute verifies the capabilities of Level 3 contractors in the United States every 3 years.

⁹⁸ The full list is available here: <https://www.cisa.gov/safecom/emergency-comms-grants-list>.

⁹⁹ The Chlorine Institute maintains a list of CHLOREP contractors on its website; the list is accessible at <https://www.chlorineinstitute.org/chlorepe-contractors>.

1.9.4 Firefighter Training Requirements

The EPFD is a volunteer fire department that performs fire suppression and other related emergency services for East Palestine, Ohio. In 2023, it had 39 personnel trained for fire response, EMS, or both. The EPFD fire chief was the only professional firefighter in the department. Training for volunteer and professional firefighters in Ohio is regulated under the State of Ohio Revised Code Section 4765.55.¹⁰⁰ The statute assigns responsibility for training and establishes limits for volunteer firefighter training programs:

The executive director of the state board of emergency medical, fire, and transportation services, with the advice and counsel of the firefighter and fire safety inspector training committee of the state board of emergency medical, fire, and transportation services, shall assist in the establishment and maintenance by any state agency, or any county, township, city, village, school district, or educational service center of a fire service training program for the training of all persons in positions of any fire training certification level approved by the executive director, including full-time paid firefighters, part-time paid firefighters, volunteer firefighters, and fire safety inspectors in this state. The executive director, with the advice and counsel of the committee, shall adopt rules to regulate those firefighter and fire safety inspector training programs, and other training programs approved by the executive director. The rules may include, but need not be limited to, training curriculum, certification examinations, training schedules, minimum hours of instruction, attendance requirements, required equipment and facilities, basic physical requirements, and methods of training for all persons in positions of any fire training certification level approved by the executive director, including full-time paid firefighters, part-time paid firefighters, volunteer firefighters, and fire safety inspectors. The rules adopted to regulate training programs for volunteer firefighters shall not require more than thirty-six hours of training. (State of Ohio Revised Code Section 4765.55)

Under this section, training programs for volunteer firefighters cannot require more than 36 hours of training.

¹⁰⁰ The code has been revised three times since the East Palestine derailment. The version here cited was the one effective at the time of the derailment, last modified October 9, 2021.

The training program and formal Volunteer Firefighter certification is described on the Ohio Division of Emergency Medical Services (Ohio EMS) website. The program is characterized as an “awareness-level course” and is intended to provide a foundation for further training (Ohio EMS 2023). Because of the 36-hour statutory maximum for training, the course does not permit training in hazardous environments:

As an awareness-level course, the Ohio Volunteer Firefighter Course is intended to be a foundation upon which firefighters can begin to build their training portfolio. Due to the 36-hour time constraint as set forth in section 4765.55 of the Ohio Revised Code, the Ohio Volunteer Firefighter course limits exposures to hazardous environments as described in the Ohio Administrative Code. The course does not permit student participation in any instruction involving the type of hazardous environments in which their fire department may operate. Prohibited activities include environments which are considered to be “Immediately Dangerous to Life or Health” (IDLH), including but not limited to, hot zone operations at uncontrolled fires or hazardous materials releases involving fixed structures, mobile equipment, or outdoor areas as well as operation of emergency vehicle apparatus.

Due to the limitations of the Ohio Volunteer Firefighter Course, firefighters certified to the Volunteer Firefighter level shall be provided the additional training necessary to participate in fire department activities that exceed the training provided in the Volunteer Firefighter Course. The fire chief or the authority having jurisdiction (AHJ) is responsible to provide additional proper training in these expanded areas if the firefighter is expected to function safely within an IDLH environment or operate emergency vehicle apparatus. (Ohio EMS 2023, emphases in original)

Ohio EMS describes Ohio firefighter training curricula in course packets for its Certified Volunteer Firefighter Course, Firefighter I Course, and Firefighter II Transition Course. The Certified Volunteer Firefighter Course specifies a maximum of 36 hours of training (Ohio EMS 2019c). The course includes goals and instruction times for topics including scene safety (40 minutes), firefighter survival (50 minutes), use of portable fire extinguishers (130 minutes), use of a self-contained breathing apparatus (3 hours), and deployment of hoses (6 hours). Ohio EMS notes that the Ohio volunteer course does not meet the minimum Standard for Fire Fighter

Professional Qualifications established by the National Fire Protection Association (NFPA) as NFPA 1001.¹⁰¹

The Firefighter I Course specifies a minimum of 160 hours of training, including 5 hours of “live fire” training in actual fire suppression (Ohio EMS 2019a). In general, the course addresses in greater depth subjects covered under the volunteer training; for example, instruction time for use of a self-contained breathing apparatus is expanded to 14 hours. The course makes numerous references to NFPA standards, including the NFPA 1001 firefighter standard and NFPA 1072 hazardous materials awareness and operations standard. The course specifies 16 hours of cognitive training and 8 hours of practical training in hazardous materials awareness and operations. According to Ohio EMS, the Ohio Firefighter I certification meets the NFPA 1001 standard.

The Firefighter II Transition Course lists the Firefighter I Course as a prerequisite and specifies an additional 84 hours of training, including 14 hours of live fire training (Ohio EMS 2019b). In addition to further instruction on subjects covered in the Firefighter I Course, the Firefighter II Transition Course includes training on the Incident Command System and how to assume, transfer, and terminate command, along with advanced fire suppression techniques for flammable gas cylinders and flammable or combustible liquids. The Firefighter II certification is typical for career firefighters.

The EPFD fire chief was a career firefighter with a Firefighter II certification, which included training at the hazardous materials technician level.¹⁰² The EPFD deputy fire chief was a volunteer with a Volunteer Firefighter certification, and he had also completed hazardous materials awareness- and operations-level trainings in 2022. According to training records reviewed by the NTSB, the training levels of the rest of the department ranged from no hazardous materials training to technician-level training.

¹⁰¹ Effective January 10, 2024, the NFPA 1001 standard has been combined into the current NFPA 1010 Standard on Professional Qualifications for Firefighters. The NFPA 1010 standard requires a minimum of 160 hours of training for a professional firefighter.

¹⁰² In increasing order of capability, the four levels of hazardous materials response training are awareness, operations, technician, and specialist. See 29 *CFR* 1910.20.

1.9.5 Placarding

Federal regulations at 49 *CFR* Part 172 Subpart F establish requirements for placarding of hazardous materials offered for transportation. In general, a railcar containing any quantity of hazardous material must be placarded on each side and at each end in accordance with the naming conventions and placard design requirements set throughout the subpart. Figure 25 shows an example of an intact replacement placard affixed to a derailed tank car after fires were extinguished.



Figure 25. Replacement placard on a derailed DOT-105 tank car containing isobutylene.

Federal placarding requirements include a performance standard for durability; under 49 *CFR* 172.519, placards must be capable of withstanding 30 days of exposure to open weather conditions without deterioration or a substantial reduction in effectiveness. The performance standards do not extend to postaccident survivability in a fire. Federal regulations allow placards to be made of any plastic, metal, or other material that can meet the performance standard, though if the

placard is made of tagboard, the tagboard must meet minimum thickness and weight requirements.

The 2020 ERG, effective at the time of the East Palestine derailment, advises emergency responders to use placards to identify hazards and relevant ERG guidance if identification numbers or proper shipping names are not available (PHMSA 2020). When attempting to read placards, emergency responders should approach from upwind, uphill, and upstream and remain at a safe distance. If possible, they should use binoculars. If multiple placards are present and reference multiple guides within the ERG, responders should base their precautions on the guide requiring the greatest degree of protective actions (PHMSA 2020). The 2024 ERG contains the same guidance regarding use of placards (PHMSA 2024).

When interviewed by the NTSB, the EPFD deputy fire chief reported that the placards affixed to several railcars had sustained damage and became illegible after being exposed to heat. The NTSB photographed several damaged placards during its on-scene investigation. Figure 26 provides two examples.



Figure 26. Postderailment photographs of placards exposed to heat.

1.10 Vent and Burn Frequency and Guidance

ESI is a contractor that provides vent and burn services. When interviewed by the NTSB, ESI's president said that railroads bring in his company as a last resort and that it had been about 3 years since he had last conducted a vent and burn. He characterized vent and burn procedures as very infrequent and undertaken by railroads only after the exhaustion of safer options. Describing ESI's role in the decision to undertake a vent and burn, he said:

We have a role to do what I would consider what's morally and legally right to do. We're not going to just go in and do a vent and burn because we want to, you know, clean the site up. So what we do is we base our decision off what the railroad and the railroad's contractors have provided to us. But, as far as the final decision, that's usually done through the railroad, through the incident command structure, and then we're granted permission to do it based on the actual last... resort of being able to remediate the site.

MxV Rail's Security and Emergency Response Training Center provides guidance for vent and burn procedures as part of its tank car specialist training curriculum.¹⁰³ The training literature states that vent and burn should be considered when, after a thorough damage assessment, it is determined that the railcar cannot be moved safely and that there is no way to transfer the lading. It further states that venting and burning will resolve other problems, such as pressure buildup with potentially catastrophic results. The course material states that vent and burn is not an easy choice to make and should be used as a last resort.

In 1994, the FRA published a research report and accompanying practical handbook on the vent and burn method. The FRA commented in the 1994 report that "the lack of a standardized procedure has made each application unique and dangerous, and that several past field applications have failed to cut the desired hole and even resulted in tank failure" (FRA 1994). The research report lists "vinyl chloride" among the candidate products for vent and burn and notes a historical case of a vent and burn procedure on tank cars containing vinyl chloride: a vent and burn of several tank cars following a derailment in Muldraugh, Kentucky, in 1980.¹⁰⁴

The 1994 handbook recommends the vent and burn process when all other emergency product removal methods have been considered and rejected (FRA 1994). According to the handbook, the vent and burn method may be used when the following conditions exist:

¹⁰³ The Security and Emergency Response Training Center tank car specialist course is a 5-day, 40-hour training that covers mitigation techniques for railroad incidents, including product transfer, containment methods, use of special containment devices, and flaring operations. The course covers rail vehicle threat and vulnerability assessments, including actions and responses to toxic or industrial hazardous materials releases. See course number PER-290 at <https://sertc.org/courses/tcs/>.

¹⁰⁴ The NTSB investigated this derailment and issued an investigative report focused on the derailment itself. The NTSB made no findings specific to the vent and burn but noted that postaccident emergency activities were "carried out in a coordinated and effective manner" (NTSB 1981).

- The tank car has been exposed to fire resulting in elevated internal pressure and possible tank damage.
- The tank car has been structurally weakened to an extent that it cannot be safely rerailed and moved to an appropriate unloading point.
- Site conditions prevent the use of cranes or other rerailing equipment.
- Conditions do not allow for the safe transfer, venting, or flaring of the tank car.
- Damage to leaking valves and fittings cannot be repaired.

Candidate products for the vent and burn method include:

- Flammable compressed gases such as propane, butane, or butadiene.
- Flammable or combustible liquids.
- Products subject to polymerization and shipped with inhibitors that can be lost in a fire situation, making rapid unloading necessary.

Both the 1994 report and handbook state that any product with a secondary hazard of “poison-inhalation hazard” should not be considered for a vent and burn, and that a vent and burn may release harmful byproducts of oxidation.

The handbook notes that the risks associated with this procedure include:

- The tank car could fail during the vent and burn due to undetected material flaws or improper application of explosives, resulting in injury to personnel and damage to property and the environment.
- There is no way to control the flow of product once the tank shell is breached.
- Multiple entries into the incident scene may be necessary for the application of explosives.

The handbook further recommends that a written plan of operation and a site safety plan should be prepared to ensure that all parties involved have a clear understanding of the impending actions.

In 2007, the FRA published the results of a study on the vent and burn method, building on the 1994 FRA research report and associated handbook. The resulting reports (Tank Car Vent and Burn Process Study: Phase I; and Tank Car Vent and Burn Process Study: Phase II) include detailed information about vent and burn procedures. Because the reports included detailed discussions of explosives, the reports were classified as Sensitive Security Information under 49 *CFR* Part 1520 and were not available to the general public until May 6, 2024, when the FRA released

public versions.¹⁰⁵ The 2007 reports also describe in greater detail the vent and burn criteria for specific ladings and include guidance not available in the 1994 handbook. The Phase II report recommends that:

- Incident commanders should use the included 24-item vent and burn checklist (see figure 27).
- Incident commanders should use the included vent and burn flowchart or process map.
- Incident commanders should use the vent and burn database as a valuable resource as they prepare for a vent and burn.
- Incident commanders should use the vent and burn report form contained in an appendix to the report to document important variables and events surrounding a vent and burn.

¹⁰⁵ (a) The NTSB obtained permission to disclose limited information from the reports during our Investigative Hearing. (b) Although now available through the FRA's website, both reports are still marked "Limited Distribution."

Appendix A.

Vent and Burn Checklist

(Place a check mark in the box next to the response that best describes the situation.)

Damage Assessment

Is tank car being impinged upon by fire?	Yes		Close to Fire		No	
Are contents of tank car burning?	Yes				No	
Is tank car venting continuously?	Yes				No	
Is shell rupture imminent?	Yes		Possible		No	
Is tank damaged?	Yes		Somewhat		No	
Has tank specification and construction material been determined?	Yes				No	
Is ambient temperature cold enough to cause brittle fracture?	Yes		Possible		No	

Location/Environment/Site Assessment

Is the tank close to other tank cars?	Yes		Somewhat		No	
Is the tank near buildings or structures?	Yes		Somewhat		No	
Is tank near habitation?	No		Within .025 mile		Within 0.5 mile	
Have inhabitants been evacuated?	Yes		In process		No	
Is excavation of burn pit possible?	No		Within .025 mile		Within 0.5 mile	
Is accident scene close to water sources?	No		Within .025 mile		Within 0.5 mile	
Will windspeed and direction produce dangerous product fallout?	Yes		Somewhat		No	

Product Considerations

Is product combustible?	Yes				No	
Is product polymerization a possibility?	Yes				No	
Will controlled release exceed toxicity levels?	Yes				No	
Will products of combustion exceed toxicity levels?	Yes				No	
What is the permeability of the soil?	High		Medium		Low	
What is the viscosity of the product?	High		Medium		Low	

Resources/Product Containment

Are local fire suppression personnel present?	Yes		On Call		No	
Is equipment available to dig pit and trench?	Yes		En route		No	
Is an explosives expert available?	Yes		En route		No	
Are proper explosives available?	Yes		En route		No	

Figure 27. FRA vent and burn checklist. (Courtesy of the FRA.)

The flowchart includes confirming that all alternatives to a vent and burn have been considered, ascertaining whether the product is suitable for a vent and burn, and creating a site safety plan. The checklist also advises incident commanders to consider toxic or otherwise hazardous combustion products from a vent and burn along with the consequences of an uncontrolled release of the product itself.

The report describes the database as “containing the itemized checklist, tank car material specifications, Universal Machine Language Equipment Register information, and commodity characteristics ... developed in a format compatible with personal digital assistants and laptop computers” (FRA 2007a). The report provides screenshots and sample tables showing how to use the database, including a table titled “Hazard material class 2.1, flammable gas, suitable for V&B action” (FRA 2007a). Vinyl chloride is not listed in the table. The Phase I report includes additional tables and notes two chemical hazards associated with a vent and burn of vinyl chloride that make it “less suitable” for the method: self-reactivity if exposed to fire for a long duration and potential shock sensitivity (FRA 2007b).

The report makes reference to a compact disc containing a database compatible with Microsoft Access along with forms for providing information for the database, but the NTSB found no evidence that the database described in the Phase II report has been maintained, updated, or entered general use.

The incident command did not use the 1994 FRA report or handbook, or the 2007 FRA reports, as a reference for the East Palestine vent and burn. The NS hazardous materials regional manager, present at the scene, was one of the five authors of the 2007 FRA study while employed by the AAR. At the NTSB Investigative Hearing, he testified that he was not aware of the tools in this study being used in the lead-up to the vent and burn procedure at East Palestine.¹⁰⁶ The 2007 FRA reports were not available to the incident commander, and he was not aware nor made aware that such reports existed. The NTSB did not find evidence of formal checklists being prepared or used by NS or its contractors before the vent and burn.

1.11 Rules and Requirements for Hazardous Materials Trains

1.11.1 Key Trains and Key Routes

The AAR defines a key train in Circular OT-55-R as any train containing one tank car load of poison or toxic inhalation hazard, anhydrous ammonia, or ammonia

¹⁰⁶ NTSB Investigative Hearing Transcript, Day 2, pp. 404-5.

solutions; 20 car loads or intermodal portable tank loads of hazardous materials; or one or more car loads of spent nuclear fuel or high-level radioactive waste (AAR 2024a).¹⁰⁷ The circular restricts key trains to 50 mph, requires the use of roller bearings, and requires that:

If a defect in a "Key Train" bearing is reported by a wayside detector, but a visual inspection fails to confirm evidence of a defect, the train will not exceed 30 mph until it has passed over the next wayside detector or delivered to a terminal for a mechanical inspection. If the same car again sets off the next detector or is found to be defective, it must be set out from the train. (AAR 2024a)

The AAR defines a key route in Circular OT-55-R as:

Any track with a combination of 10,000 car loads or intermodal portable tank loads of hazardous materials, or a combination of 4,000 car loadings of [poison or toxic inhalation hazard] (Hazard zone A, B, C, or D), anhydrous ammonia, flammable gas, Class 1.1 or 1.2 explosives, environmentally sensitive chemicals, Spent Nuclear Fuel (SNF), and High Level Radioactive Waste (HLRW) over a period of one year. (AAR 2024a)

AAR recommended practices specify that key routes have wayside bearing defect detectors spaced a maximum of 40 miles apart or that railroads install an equivalent level of protection using improved technologies. Main track on key routes must be inspected twice each year with rail defect detection and track geometry inspection cars, and sidings must receive these inspections at least once each year. Track used for meeting and passing key trains must be Class 2 or higher, and if a meet or pass must occur on a lesser class of track because of an emergency, one of the trains must stop before the other passes (AAR 2024a).

Train 32N was not a key train under the definition in OT-55-R because it did not include a total of 20 tank cars carrying hazardous materials or any of the specific hazardous materials identified in the definition. The AAR has not publicly identified the track involved in the East Palestine derailment as part of a key route, but the track

¹⁰⁷ This version of Circular OT-55-R is effective as of February 12, 2024. The version in effect at the time of the East Palestine derailment included the phrase "20 car loads of any combination of hazardous materials" in its definition of a key train. The updated circular notes that the change was made to resolve a discrepancy between the circular and the definition of a key train used in the *United States Hazardous Materials Instructions for Rail*, another AAR product.

exceeded Class 2 and had bearing defect detectors installed less than 40 miles apart near the derailment site.

1.11.2 High-hazard Flammable Trains and Key Trains

On August 1, 2014, PHMSA published a notice of proposed rulemaking (NPRM) in the *Federal Register* (Fed. Reg.) proposing a definition for a high-hazard flammable train (HHFT), a class of train that would be subject to requirements intended to reduce the probability and severity of flammable materials releases (79 Fed. Reg. 45016).¹⁰⁸ The NPRM defined an HHFT as any train with 20 or more tank cars of a Class 3 flammable liquid. Final rule HM-251, published May 8, 2015, defined an HHFT as:

...a train comprised of 20 or more loaded tank cars of a Class 3 flammable liquid in a continuous block or 35 or more loaded tank cars of a Class 3 flammable liquid across the entire train.
(80 Fed. Reg. 26645)

In the final rule, PHMSA explained the revised definition as intended to focus HHFT requirements on trains transporting large quantities of ethanol or crude oil “while not affecting lower-risk trains that are not transporting similar bulk quantities of Class 3 flammable liquids” (80 Fed. Reg. 26645-26646).

The FAST Act, signed into law on December 4, 2015, defined an HHFT in Section 7302 as:

...a single train transporting 20 or more tank cars loaded with a Class 3 flammable liquid in a continuous block or a single train transporting 35 or more tank cars loaded with a Class 3 flammable liquid throughout the train consist. (PL 114-94)

The FAST Act also directed the Secretary of Transportation to issue regulations to require each Class I railroad to provide advanced notification and information on HHFTs to each state’s emergency response commission, including identification and a description of the Class 3 flammable liquid being transported, ERI, identification of the routes over which such liquid will be transported, and a railroad point of contact

¹⁰⁸ The NPRM was partially in response to NTSB safety recommendations. This subject is discussed in section 2.4.4.

responsible for communicating with state emergency response centers and local emergency responders (PL 114-94).

Current federal regulations at 49 *CFR* 171.8 reflect the tank car counts in the final rule and FAST Act: an HHFT is a single train with 20 or more loaded tanks carrying a Class 3 flammable liquid in a single block, or a single train with 35 or more such tank cars throughout the consist. Under 49 *CFR* 174.310, HHFTs must follow special routing and planning requirements described in 49 *CFR* 172.820, not exceed 50 mph, and be equipped with a two-way braking system or distributed power system if operating above 30 mph. The same regulation requires that tank cars manufactured after October 1, 2015, for use in an HHFT must meet the DOT-117 specification or another authorized specification as stated in 49 *CFR* Part 174 Subpart F. Regulations for advanced notification and provision of HHFT information to state emergency response commissions are established in 49 *CFR* 174.312.

Train 32N was transporting hazardous materials but was not an HHFT under any definition discussed in this section; it included fewer than 20 tank cars of Class 3 flammable liquid.

1.11.3 Consist Notification

1.11.3.1 Industry Standards and NS Rules

The AAR *United States Hazardous Materials Instructions for Rail*, commonly adopted by railroads as HM-1, includes guidelines for train crews following accidents involving hazardous materials (AAR 2022b). The NS version of HM-1 directs crews to make an emergency call during an emergency as radio rules require and provide the train dispatcher or yardmaster with as much relevant information as possible, including the specific location of the emergency, what railcars are involved, and the status of crewmembers. HM-1 also directs crews to immediately share any requested information from shipping documents with emergency responders, provide an extra copy of the train consist if one is available (crews are instructed to retain a copy of the train consist until it can be delivered to a railroad manager on the scene), and help emergency response personnel identify railcars and involved commodities while remaining at a safe distance.

1.11.3.2 Regulatory Requirements

ERI requirements for carriers (such as railroads) are established in 49 *CFR* Part 172 Subpart G. Under 49 *CFR* 172.600, a carrier may not accept hazardous material for transportation, unless (1) ERI conforming to Subpart G is

immediately available for use at all times the hazardous material is present and (2) ERI required by Subpart G is immediately available to any person who, as a representative of a government agency, responds to a hazardous materials incident or is conducting a hazardous materials investigation.

1.12 NTSB Special Investigation

In March 2023, the NTSB announced that we would conduct a special investigation of NS's organization and safety culture. The East Palestine derailment is one accident that led to the NTSB's decision to undertake a special investigation.

The NTSB's postderailment examinations of non-derailed equipment from train 32N identified FRA-reportable defects on 26% of the railcars, all of which had received NS or TRRA mechanical inspections. Most defects were minor. One railcar had a major defect: a missing cross-key retainer.¹⁰⁹ At the NTSB's Investigative Hearing, a representative of the Brotherhood of Railway Carmen/Transportation Communications Union testified about decreasing freight car inspection times afforded to inspectors at NS railyards.¹¹⁰ The NTSB also obtained a copy of an email an NS senior general foreman sent to his team referring to the need to improve inspection times and appearing to state a target time of 90 seconds for both inbound and outbound railcars. NS did not inspect the hopper car relevant to the East Palestine derailment because it had been added to the train in the TRRA yard, but the NTSB will further explore the issue of inspection times as part of our special investigation.

Other accidents involving NS and under investigation at the time of the announcement included:

- Reed, Pennsylvania (RRD22LR003)
- Bessemer, Alabama (RRD23LR003)
- Anniston, Alabama (RRD23LR008)
- New Castle, Pennsylvania (RRD23FR011)

¹⁰⁹ A *cross-key retainer* is a railcar component that prevents dislodging of the cross key (also called the draft key) that secures the coupler assembly to the railcar.

¹¹⁰ NTSB Investigative Hearing Transcript, Day 2, pp. 263-5.

- Elliston, Virginia (RRD23FR013)¹¹¹

In addition to these investigations, the NTSB has conducted a survey of all 20,000 NS employees and begun an analysis of safety data. The results of the survey and safety data analysis will shape the direction of the special investigation.

1.13 Postaccident Actions

1.13.1 PHMSA

1.13.1.1 Aluminum Protective Housing Covers

In response to the East Palestine derailment, on March 2, 2023, PHMSA issued Safety Advisory Notice for Tank Cars Equipped with Aluminum Manway Protective Housing Covers to hazardous materials tank car owners and offerors (PHMSA 2023d). The safety advisory noted that while the effects of the melting aluminum covers was still under investigation, PHMSA was concerned that these covers may present a danger in pool fire situations. PHMSA requested that tank car owners and offerors survey their fleets to identify tank cars with aluminum protective housing covers and consider replacing them with carbon steel covers.

1.13.1.2 Consist Notification

On March 3, 2023, PHMSA issued Safety Advisory Notice for Railroad Emergency Preparedness to railroads to review access to the AskRail application among emergency response agencies along their routes (PHMSA 2023c).¹¹² The safety alert also noted the availability of PHMSA grants to support training resources to first responders and urged railroads to review, update, and disseminate emergency response plans among emergency response agencies, conducting

¹¹¹ As of this report's publication, these investigations are completed with published reports (Reed, Pennsylvania, and Bessemer, Alabama), will be closed without a final report (New Castle, Pennsylvania, and Elliston, Virginia), or are still in progress (Anniston, Alabama).

¹¹² AskRail is a software application developed by the North American Class I railroads and intended to provide pre-qualified personnel, such as emergency responders, with information about train consists. As discussed in section 1.1.2, the Beaver County director of emergency services and chief of hazard materials told the NTSB that he attempted to access the AskRail application using a laptop on the night of the derailment but was not initially successful. He said that the application began working about 2:00 a.m. on February 4, 2023. The East Liverpool fire chief told the NTSB in his interview that his hazardous materials team used a cell phone to access the AskRail application and obtain the train 32N consist before reaching the scene on the night of February 3, 2023.

training exercises as needed to ensure that communities are prepared for emergencies.

On June 27, 2023, PHMSA published an NPRM titled Hazardous Materials: FAST Act Requirements for Real-Time Train Consist Information, proposing amendments to its rules for hazard communication (88 Fed. Reg. 41541). The proposed amendments would require railroads to:

- Promptly forward train consist information to state-authorized local first responders within a 10-mile radius of an incident or accident involving the release or suspected release of hazardous materials.
- Generate, maintain externally to the train itself, and update in real time accurate train consist information in electronic form and make this information available to authorized first responders, emergency response officials, and law enforcement personnel at all times upon request.

On July 11, 2023, in coordination with the FRA, PHMSA issued Safety Advisory Notice Encouraging the Use of Real-Time Train Consist Information in 9-1-1 Call Centers, encouraging 911 call centers to download available resources, specifically the AskRail application, and use these resources to provide information about train consists to first responders (PHMSA 2023a).

On June 24, 2024, PHMSA published Final Rule HM-263 (89 Fed. Reg. 52956). Under the new rule, any railroad transporting hazardous materials must create and maintain accurate consist information for hazardous materials trains external to the train itself and in electronic form. This consist information must be immediately available to federal, state, and local first responders, emergency response officials, and law enforcement personnel upon request. For Class I and Class II railroads, the final rule further requires that:

In the event of either an accident involving a train carrying hazardous materials, or incident involving the release or suspected release of hazardous material, railroads operating trains carrying hazardous material are required to immediately notify the primary PSAP responsible for the area where the incident occurred telephonically and the track owner (if the track owner and the railroad operating the train are different), and provide the train consist information to the primary PSAP/track owner electronically in a form that the PSAP/track owner is capable of readily accessing (i.e., a form the PSAP/track owner can

access and use based on the specific information technology resources they have available) to assist in response and investigation efforts. This emergency notification requirement applies to situations that require response from local emergency response agencies. (89 Fed. Reg. 52957-52958)

Class III railroads may comply with the requirements described above or may use alternative means to provide consist information to emergency responders. If using an alternative means, a Class III railroad must develop a written plan documenting their alternative approach to providing consist information to PSAPs and local response agencies along its routes and conduct annual tests to demonstrate that their plan is effective (89 Fed. Reg. 52958).

Class I railroads must comply with these requirements within 1 year. Class II and III railroads must comply within 2 years.

1.13.1.3 DOT-111 Tank Cars in Flammable Liquids Service

On March 22, 2023, PHMSA issued Safety Advisory Notice for DOT-111 Tank Cars in Flammable Liquid Service to all entities using DOT-111 and CPC-1232 tank cars in flammable liquids service. PHMSA advised these entities to consider removing DOT-111 and CPC-1232 tank cars from service and replacing them with DOT-117 or DOT-117R tank cars as soon as practicable (PHMSA 2023b). PHMSA also recommended that rail carriers determine whether applying requirements for HHFTs to trains with fewer tank cars carrying flammable liquids is appropriate to ensure safe operations.

In the same safety advisory, PHMSA indicated that it believes an accelerated phase out of DOT-111 tank cars is technically possible:

PHMSA believes that it is possible, and in the clear safety interest of the public, for tank car owners and shippers using DOT-111 tank cars to acquire the DOT-117J, or even DOT-117R, specification tank cars they need to continue operating well before the May 1, 2029, phase out. There is sufficient shop capacity to retrofit existing tank cars to the DOT-117R standard and to build new DOT-117J tank cars to replace the existing DOT-111 tank car and CPC-1232 tank car fleet. (PHMSA 2023b)

1.13.1.4 Placard Survivability

PHMSA partners with the Volpe Center's Small Business Innovative Research Program to encourage domestic small businesses to conduct research and

development on various topics. On February 8, 2024, the Volpe Center opened a solicitation for businesses to apply for Phase I grants (up to \$200,000) to complete proof-of-concept work on placard survivability.¹¹³

1.13.2 FRA

1.13.2.1 NS Safety Assessment

Following the East Palestine derailment, the FRA conducted a safety assessment of NS from March 15 to May 15, 2023 (FRA 2023). The safety assessment included an evaluation of NS responses to previous FRA safety recommendations; inspections and investigations of safety-critical elements of NS operations; and surveys of NS employees and frontline supervisors in addition to semi-structured interviews (fixed questions with open-ended responses) of NS leaders and local labor leaders who were also NS employees.

As a result of this safety assessment, the FRA made 4 overall findings and 19 overall recommendations to NS in addition to more specific findings and recommendations; the overall findings and recommendations are quoted below:

FRA Finding 1:

NS Communications [*sic*] are not always open and effective and require improvement.

FRA Recommendations:

1. Evaluate the communications processes surrounding responses to wayside detector alerts and alarms to identify and eliminate gaps and delays.
2. Develop a new (or refine existing) policy that outlines how information will flow throughout the organization.
3. Review NS' communication policy and update it, as appropriate.
4. Inform all levels of management as well as employees about the communication methods and protocols NS will use to disseminate information.
5. Clarify where specific information can be located and what (if any) information is available via more than one method.

¹¹³ A summary of the solicitation and topics for fiscal year 2024 is available here: <https://www.volpe.dot.gov/work-us/small-business-innovation-research/fy241-sbir-solicitation-now-open>.

6. If older communications systems (e.g., oral briefings, posted signage) are being phased out or eliminated in favor of electronic communications, ensure all employees are aware of this change and able to access the electronic systems.

FRA Finding 2:

NS employees and the organization do not always work to foster mutual trust.

FRA Recommendations:

1. Participate in the Confidential Close Call Reporting System (C³RS) to allow employees to anonymously report safety close calls without fear of discipline or enforcement.
2. Continue to explore ways to increase trust.
3. Review existing discipline programs and ensure their application is consistent across locations and managers.
4. Develop and implement a policy for responding promptly and as publicly as possible to complaints.
5. Engage with employees and solicit feedback on their perceptions of the current state of trust at NS and how that could be improved and use that feedback to create action items designed to foster trust.
6. Include employees, and their representatives, in as many processes as possible including when required by regulation to consult with directly affected employees such as with 49 *CFR* Part 271: Risk Reduction Programs and Fatigue Risk Management Program.

FRA Finding 3:

NS Training and resources are not always effective at supporting safety efforts.

FRA Recommendations:

1. Create additional opportunities for employees to complete both required "rules class" trainings as well as supplemental safety training courses offered by NS during on duty hours. Consider taking concrete steps to set aside specific duty time for employees to participate in safety training opportunities.
2. Explore additional methods for evaluating the effectiveness of training, and develop and implement corrective actions in response to any findings.

3. Consider the methods that are used to administer training and explore the feasibility of offering more than one delivery method for trainings to account for the differences in learning styles and preferences of adult learners. In the absence of alternatives to online training, utilize a variety of instructional methods, such as text, narration, video segments, interactive features, and the ability to apply what has been learned to engage with as many different types of learners as possible.
4. Review the training offered to frontline supervisors and make changes, as needed, to ensure that frontline supervisors are trained in leadership skills and understand how they are empowered to do their jobs. Ensure that frontline supervisor training is of sufficient length, quality, and content to enable supervisors to lead their teams effectively and safely.

FRA Finding 4:

NS frequently focused solely on compliance with minimum safety standards.

FRA Recommendations:

1. Leverage partnerships with recently engaged safety culture consultants to review and act on the findings and recommendations in this report. Identify the policies and actions that have led to the observed positive results and determine how these successes can be improved upon, and how this information can be leveraged in other areas of the NS safety culture.
2. Explore ways, including developing corrective actions for previous safety recommendations which may go beyond minimal regulatory standards, to move from systems that are reactive and focused on lagging safety indicators to those which are proactive and focus on leading safety indicators.
3. Consider FRA's findings when conducting hazard identification and risk analysis as well as in the implementation of NS' Risk Reduction Program and Fatigue Risk Management Program.

1.13.2.2 DOT-111 Phase Out

On January 19, 2024, the FRA published a report describing the results of the FRA's Legacy Tank Car Focused Inspection Program, a program undertaken in response to the East Palestine derailment that focused inspection resources on DOT-111 tank cars and the shippers and tank car owners that have not yet upgraded to the DOT-117 specification (FRA 2024). The resulting inspections, conducted

between March 2023 and August 2023, included tank car owners that collectively own and control about 85% of the North American tank car fleet. The FRA found that some large tank car fleet owners have established retrofit programs, based on FAST Act compliance dates, to retrofit, scrap, and retire DOT-111 cars by the deadline and, in some cases, are implementing programs to move DOT-111 cars into services other than the transportation of flammable liquids. The FRA also found that while these tank car owners are on track to meet the May 2029 DOT-111 phase out, economic and practical challenges remain that prevent full-scale removal of the DOT-111 cars from service. Further, the FRA found that the cost and limited manufacturing capacity of new DOT-117 cars and corresponding lease rates of DOT-117 cars provided a disincentive for tank car owners and shippers to phase out DOT-111 cars faster than required, and that some existing long-term lease agreements between car owners and shippers are not subject to revision. However, the FRA also noted that the Railway Supply Institute has previously indicated that it may be technically and operationally feasible to accelerate the May 2029 phase-out deadline by 1 year.

1.13.3 Norfolk Southern

NS provided the postaccident actions described below in a letter to the NTSB.

1.13.3.1 Emergency Response

As a result of the East Palestine derailment, NS reported that it has begun integrating its emergency response notification process with RapidSOS, a digital platform designed to provide emergency responders with real-time consist information and notify NS of 911 calls reporting track emergencies in NS's rail network. RapidSOS automatically provides dispatch centers equipped with its software information about an emergency alert, such as the consist of a derailed train; the dispatch center can then send this information to first responders' mobile devices.

On September 21, 2023, NS began construction of a new first responder training center in East Palestine, Ohio. NS plans to cover the new center's operating costs for the next 10 years. NS intends the new center to offer both traditional fire service training and more specialized training for rail and other transportation emergencies. Planned training methods include classroom instruction, online resources, tabletop drills, and full-scale exercises.

1.13.3.2 Wayside Detection

After the East Palestine derailment, NS began increasing the number of HBDs and ABDs on its tracks. As of February 2024, NS reported that it had installed 144

new HBDs at 99 sites, reducing the average distance between HBDs from 13.9 miles to 12.28 miles. The new detectors include additional HBDs east and west of East Palestine. NS also plans to install about 140 additional HBDs on key routes, reducing the average distance between detectors on key routes to about 11 miles. NS has also increased the number of ABDs in its network from 5 to 17, which it expects will enable it to monitor 90% of railcars traveling on its main tracks annually.

In December 2023, NS installed its first multi-scan HBD, a detector designed to measure more temperature points on each bearing than current HBDs and provide algorithms with more complete information about bearing temperature.

NS reported that it has also piloted a thermal camera program at its Inman Yard in Atlanta. The pilot is intended to evaluate whether thermal cameras scanning the full face of a wheel can detect hot bearings. NS is also deploying thermal cameras as part of its development of digital train inspection portals. These portals are intended to use cameras and software to identify potential mechanical defects in trains passing at track speeds. Data from portals are relayed to the Wayside Help Desk, where analysts determine whether the data indicate a critical defect. NS deployed two portals in Leetonia, Ohio, in 2023.

On May 26, 2023, NS revised its bearing alarm criteria on its current HBD systems, eliminating the “warm bearing” category and classifying bearing temperatures more than 170°F above ambient as critical alarms. HBDs broadcast alarms to the crew immediately; the Wayside Help Desk receives a corresponding alert when the train has finished traversing the HBD.

NS is currently analyzing a year of bearing data to assess its hot bearing trending algorithms and identify opportunities for improvement. As part of this process, NS has removed, disassembled, and analyzed 108 bearings that algorithms identified as potentially problematic. NS plans to use the results of these analyses to further refine its algorithms.

Since the East Palestine derailment, NS has made changes to processes and employee resources involved in bearing defect detection. As of February 2024, NS reported that it has:

- Standardized the process that mechanical employees follow when responding to HBD alarms in the field. Mechanical employees are now instructed to contact the Help Desk before arriving on the scene and must complete a job briefing with the train crew upon arrival.

- Revised its “train matching” logic to strengthen alert communication. For an HBD to communicate an alert to the Wayside Help Desk, the software must match collected data to a specific train. NS has examined the causes for failed matches and taken steps to reduce their frequency.
- Begun developing a detector outage alert system to quickly identify nonfunctional wayside defect detectors. The planned detector outage alert system will send a notification to the Wayside Help Desk, allowing for faster dispatching of maintenance personnel.
- Supplied train crews with 5,000 handheld infrared thermometers and trained crews in their use. Certain wayside detector alarms and alerts require train crews to inspect a wheel bearing’s temperature in the field. Handheld infrared thermometers are now train crews’ primary source for field bearing temperature checks.
- Increased train crews’ and dispatchers’ real-time access to information about potential defects. Critical alerts now generate push notifications to train crews’ mobile train reporting devices and pop-up alerts to dispatch, which require acknowledgment of receipt. Alarm information is now also displayed for train crews on the PTC on-board display.
- Implemented a new handling procedure that requires a stop-and-inspect response for all bearing and wheel alerts with Kt values above six. Now, for example, when a single bearing temperature spike alert or bearing temperature deviation alert arrives at the Wayside Help Desk, in addition to following the applicable desk procedures, the analyst reviews the Kt value and intervenes if it crosses a set threshold.

1.13.3.3 Wayside Help Desk Staffing and Processes

On July 10, 2023, NS suspended its remote work policy for Help Desk personnel and hired additional staff. As of February 2024, the Help Desk has 1 senior general manager, 4 general supervisors, 12 analysts, and 4 vacation relief analysts. Three analysts and one supervisor staff most Help Desk shifts.

On August 20, 2023, NS introduced communication scripts to standardize Help Desk situational responses to train crew calls. NS has also introduced a checklist to increase and standardize communication between dispatchers, Help Desk analysts, and train crews during inspection stops in the field. NS has indicated that these changes are intended to ensure compliance with operating rules and bulletins while protecting train crews.

1.13.3.4 Industry and Union Collaboration

In February 2024, NS signed an agreement with the Brotherhood of Locomotive Engineers and Trainmen and the International Association of Sheet Metal, Air, Rail and Transportation Workers—Transportation Division to develop a Close Call Confidential Reporting pilot program.¹¹⁴ The pilot is planned to include NS's Atlanta, Georgia; Elkhart, Indiana; and Roanoke, Virginia, locations. The program will include a means for employees to report safety concerns confidentially.

¹¹⁴ The FRA sponsors a Confidential Close Call Reporting System (commonly known as C³RS). NS's communications with the NTSB refer instead to a "Close Call Confidential Reporting" pilot.

2 Analysis

2.1 Introduction

On February 3, 2023, NS freight train 32N, carrying both hazardous and non-hazardous materials, derailed in East Palestine, Ohio, shortly after triggering an HBD alarm. Derailed tank cars released lading, which ignited and led to a series of fires involving a mix of freight cars, non-hazardous materials tank cars, and hazardous materials tank cars. As emergency responders worked over the next 2 days to manage fires and protect the community, NS and its on-scene contractors expressed concerns to the incident commander that a dangerous polymerization reaction could be occurring within derailed DOT-105 tank cars carrying VCM. NS and its contractors interpreted documentation of VCM hazards, PRD activity, the detection of volatile organic compounds near a non-actuating PRD, and tank car temperature changes as indicative of dangerous polymerization within at least two tank cars (OCPX80179 and OCPX80370). NS and its contractors communicated to the incident commander that polymerization could lead to a BLEVE for at least one tank car (OCPX80370) with a large radius of destruction. The incident command and other interested entities discussed these concerns, and based on guidance provided by NS and its contractors, the incident commander authorized a vent and burn procedure, which occurred on February 6.

This analysis discusses the following safety issues:

- Failure of wayside monitoring systems to diagnose a hot wheel bearing in time for mitigation to prevent a derailment. (Section 2.2.4)
- Inadequate emergency response training for volunteer first responders. (Section 2.3.1)
- Delayed transmittal of train consist information necessary to protect first responders and the public. (Section 2.3.2)
- Illegible hazardous materials placards that prevented emergency responders from immediately identifying hazards. (Section 2.3.3)
- Continued use of DOT-111 tank cars with documented poor derailment performance and lading retention in hazardous materials service. (Section 2.4)

- Tank car certification process insufficient to ensure that tank car fittings are compatible with lading. (Section 2.4.3.1)
- Misleading written hazard information that adversely affected the vent and burn decision. (Section 2.5.2)
- Flawed communication and decision-making leading up to the vent and burn. (Section 2.5.3)

The NTSB established that the following factors did not contribute to the accident:

- *Defects in railroad track and infrastructure:* the track's condition and geometry near the derailment site did not show any defects that could have caused or contributed to the derailment.
- *Signals and train control systems:* signals and train control systems were functioning as designed at the time of the derailment.
- *The train crew's train handling and response to the bearing alarm and derailment:* the crew of train 32N acted in accordance with NS operating rules, responding appropriately to both the bearing alarm and the derailment itself.
- *The marking, placarding, and method of loading for the derailed VCM tank cars:* the VCM was loaded in a manner sufficient to stabilize the VCM for transport and was shipped under the correct proper shipping name (UN1086 vinyl chloride, stabilized, 2.1).
- *The weight and lading volume of all derailed hazardous materials tank cars:* no derailed hazardous materials tank cars were overloaded by weight or volume.
- *The mechanical crashworthiness of the derailed DOT-105 tank cars:* none of the six derailed DOT-105 tank cars sustained mechanical breaches during the derailment, including the five carrying VCM, and none released lading except through PRD activity or the vent and burn procedure.

The NTSB concludes that none of these issues contributed to the derailment of train 32N and subsequent hazardous materials release: (1) defects in railroad track or infrastructure; (2) the signals or train control system; (3) the train crew's proper train

handling and appropriate response to the bearing alarm and derailment; (4) the marking, placarding, and method of loading for the derailed VCM tank cars; (5) the weight and lading volume of the derailed hazardous materials tank cars; and (6) the mechanical crashworthiness of the derailed DOT-105 tank cars.

2.2 The Derailment

Eastbound train 32N derailed at MP 49.5, about 0.3 miles east of an HBD. Less than a minute before the derailment, this HBD broadcast a critical alarm to the crew for a left-side bearing (L1) on hopper car GPLX75465. Upon receiving the alarm, the crew acted in accordance with NS operating rules to immediately begin slowing the train in preparation for a stop. Before decelerating, the train was traveling about 43 mph, less than the maximum authorized speed of 50 mph.

While slowing and still traversing the HBD, train 32N experienced a train line-induced emergency braking application as one or more railcars became disconnected from the train. The front portion of the train slowed to a stop. The rear portion derailed 38 railcars (line numbers 25-62 inclusive), including the hopper car (line number 25).

2.2.1 Derailment Markings

The NTSB examined the track near the derailment site and identified scrape-like markings on the top of the south running rail near MP 49.5. Additional scrape-like markings extended east for more than 1,400 feet along the south running rail from MP 49.5 (no markings were found west of MP 49.5). These markings were consistent with a large metal component on one side of a railcar, likely the side frame of a truck, contacting the top of the railhead and sliding while the railcar remained in line with the track.¹¹⁵ The crossties in this area exhibited grooves consistent with derailed wheel flanges running along the ground between the rails, also indicating that a wheelset had left the rails but not yet forced its railcar out of line. Therefore, the event that precipitated the derailment pileup resulted from one railcar's side frame dropping low enough to contact the railhead on one side, which is possible only if the side frame is no longer being held above the rail by one or both of its wheelsets.

¹¹⁵ The markings were inconsistent with a wheel-climb derailment, in which a wheel flange typically climbs the side of a rail, leaves distinctive narrow marks on the top surface, and then departs the rail entirely.

One side frame contacting the track is consistent with a bearing failure and axle separation. When a bearing fails completely but remains in service, it can overheat and cause its axle to separate (“burn off”) and break the connection between the wheelset and one side of the truck. This allows the side frame to descend and contact the top of the railhead. Because the marks at East Palestine were consistent with axle separation on the south side of the train (the right side in the direction of travel) and HBD records indicated a critical alarm on a bearing on the train’s right side shortly before the derailment (the hopper car’s L1 bearing), the NTSB searched the derailment site for the wheelset and bearing identified in the alarm to determine whether other physical evidence supported bearing failure as the cause of the derailment.

2.2.2 Hopper Car GPLX75465 and L1 Bearing

The NTSB found hopper car GPLX75465 on the east side of the derailment pileup on February 4, 2023. The lead wheelset had detached from the hopper car but remained nearby, suggesting that the wheelset itself had remained attached to the railcar during the early moments of the derailment. The R1 bearing was still attached to the wheelset, but the L1 bearing and mating axle journal (the part of the axle that extends into the bearing) were missing.

The NTSB recovered components from the L1 bearing and journal near the tracks west of the derailment pileup. (See figure 28.) The components’ positions west of the pileup and far from the rest of the wheelset indicate that they became separated from the hopper car in the earliest moments of the derailment, when the hopper car was still west of its final, postderailment location.



Figure 28. Locations of derailment evidence.

The recovered L1 bearing components were heavily damaged. Two of the types of damage identified during NTSB Materials Laboratory examination—galling and rub damage—are characteristic of metal surfaces experiencing the excessive friction of a burn-off. The bearing cup showed signs of melting, another indication of excessive friction producing high temperatures and causing the bearing to overheat. The deformation of the journal from a cylinder into a cone shape was also characteristic of a burn-off.

The extent of the damage indicates that the axle journal burned off before the derailment, breaking the connection between the lead wheelset and the side frame of the lead truck. Based on the position of the recovered L1 bearing components, the friction damage to bearing components identified in laboratory examinations, track markings consistent with a bearing-failure derailment, and the triggering of an HBD critical bearing alarm less than a minute before the derailment, the NTSB concludes that train 32N derailed because the L1 bearing on railcar GPLX75465 overheated and caused the axle to separate, causing the railcar's lead truck to derail.

2.2.3 Mechanical Inspection of Hopper Car

The hopper car was visually inspected by qualified mechanical inspectors at the TRRA yard on February 1, 2023, in Madison, Illinois. When the NTSB examined non-derailed equipment after the accident, they identified multiple FRA-reportable defects on railcars that were not reported following the TRRA mechanical inspection. The number of defects identified during the NTSB's examinations calls into question the thoroughness of the 49 CFR 215 inspection performed on February 1. It is

possible that the L1 bearing was showing visible signs of failure, and that the mechanical inspection failed to identify them. However, no available evidence indicates that the L1 bearing on the hopper car was showing visible signs of deterioration on February 1. Predeparture inspections are performed visually, and the bearing components recovered after the derailment were too damaged to support a determination of how the bearing would have appeared to the TRRA mechanical inspectors. If a bearing is failing because of an internal defect, it might not show signs detectable even through a complete and thorough mechanical inspection performed in compliance with 49 *CFR* 215. The NTSB concludes that there is insufficient evidence to determine if the TRRA mechanical inspection of train 32N on February 1, 2023, failed to identify signs of failure on hopper car GPLX75465's L1 wheel bearing.

The mechanical inspection of 40 railcars added to train 32N at the NS yard on February 1 in Decatur, Illinois, did not include the hopper car; it was already part of the train's consist and was not required to be re-inspected under 49 *CFR* 215. In addition, the NS mechanical inspection failed to report FRA-reportable defects later identified on these railcars, but these unreported defects did not contribute to the derailment.

While the NS mechanical inspection of the last 40 railcars of train 32N did not contribute to the derailment, the NTSB Investigative Hearing included testimony from a representative of the Brotherhood of Railway Carmen/Transportation Communications Union that described decreasing freight car inspection times afforded to inspectors at NS railyards, and the NTSB obtained an email originally sent by an NS senior general foreman to his team that appeared to describe a goal of 90 seconds per railcar inspection.¹¹⁶ Reduced or inadequate inspection times have the potential to adversely affect the quality of an inspection program. While the evidence available from the East Palestine investigation does not support a determination of whether mechanical inspection time goals contributed to the number of unreported defects on train 32N, the subject remains of interest to the NTSB and will be further examined as appropriate as part of the NTSB's special investigation into NS's organization and safety culture.

2.2.4 Bearing Failure Detection

The NTSB reviewed surveillance camera images along train 32N's route and data from the last three HBDs it traversed before derailing. (See figure 29.) The first of

¹¹⁶ NTSB Investigative Hearing Transcript, Day 2, pp. 263-5.

these detectors, located in Sebring, Ohio, and about 30 miles west of the derailment site, did not record any bearing temperatures high enough to trigger an alert or alarm. Surveillance cameras in Sebring, Ohio, captured images of the train, and no anomalies were noted in the images.

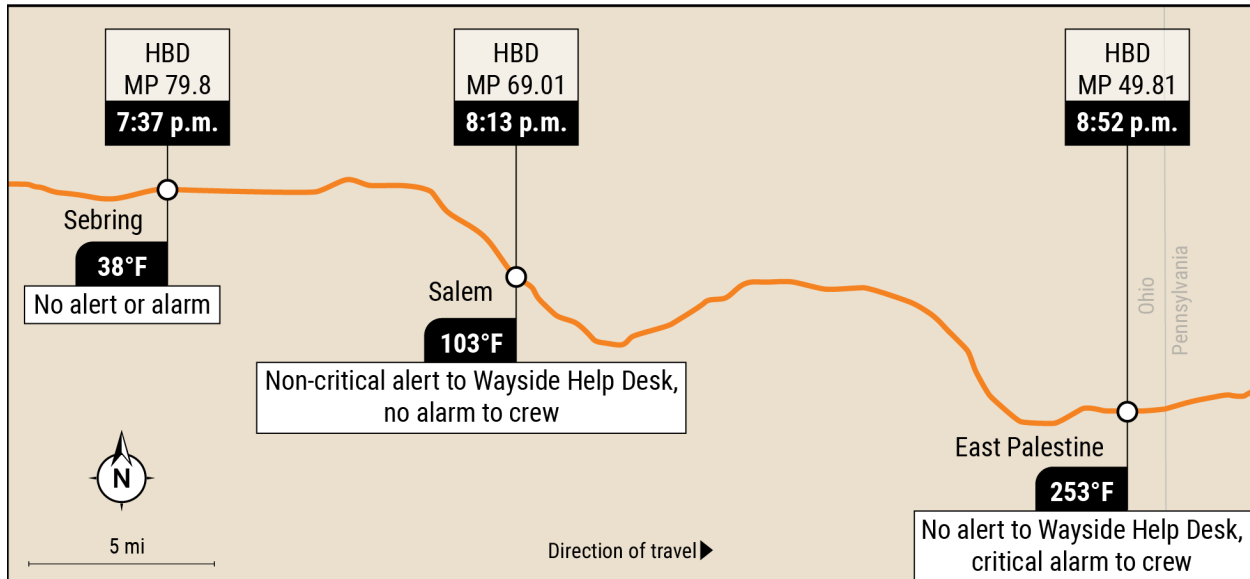


Figure 29. Summary of HBD temperature measurements, alerts, and alarms.

The first clear indications of bearing deterioration were captured by surveillance cameras in Salem, Ohio, about 19 miles from the derailment site. Images from these cameras showed a fire on the L1 bearing of the hopper car.

Shortly after the train passed the field of view of these surveillance cameras, it traversed an HBD in Salem, Ohio, which recorded a temperature 103°F above ambient on the L1 bearing of the hopper car. This measurement was below the 170°F threshold that would have triggered an alarm broadcast to the train crew, which remained unaware that a bearing was showing unusual behavior. The measurement met the NS temperature criteria to trigger a non-critical alert at the NS ATC Wayside Help Desk. The non-critical alert identified the L1 bearing as needing continued monitoring: a trend analysis based on data from additional HBDs. Because train 32N derailed before it finished traversing the next HBD (in East Palestine), this trend analysis could not take place. The analyst on duty also did not see the alert from the Salem HBD because he was working to resolve other, higher-priority alerts, but immediately seeing the Salem HBD alert would not have prevented the derailment; the train derailed before the analyst would have been required by NS procedures to take any actions.

The HBD in Salem, Ohio, was configured to take its temperature readings from the inner edge of the bearing cup. This configuration is intended to reduce the likelihood that railcar components will obstruct the HBD's view of the bearing. However, changes in temperature take time to equalize across different bearing components, meaning that as a bearing begins to overheat, the interior of a bearing may be hotter than the exterior, and two points on the exterior may differ in temperature. The fire visible in surveillance camera images indicates that at least the outer edge of the bearing was hot enough to result in the combustion of grease or another flammable substance. Part of the bearing was therefore hotter than the 103°F temperature the HBD measured at the inner edge of the bearing cup. The temperature measurement, which was likely lower than the bearing's actual highest temperature, resulted in a non-critical alert for a bearing that burned off and separated less than 20 miles later. The NTSB concludes that the non-critical alert transmitted by the Salem, Ohio, HBD did not reflect the true temperature and failing condition of the L1 wheel bearing.

It is unclear whether a different HBD design or configuration would have provided a more accurate measurement of the bearing's temperature. The NTSB's review of existing research on HBDs found that variations in railcar design pose significant challenges to measuring temperatures near the center or outer edge of the bearing cup; parts of the railcar's trucks can obstruct the HBDs field of view (Carter and Clasby 2017). Further, measuring a different or larger surface area of the bearing cup does not ensure that the measurement will include the hottest part of the bearing, which may be inside the bearing or outside the HBD's field of view. As discussed during the Investigative Hearing, changes in the exterior temperature of a bearing tend to lag behind changes in the interior temperature.¹¹⁷ The NTSB concludes that a failing wheel bearing's actual internal temperatures will likely exceed external temperatures measured and reported by an HBD, and this limit on HBD accuracy is inherent in how current HBDs and railcar trucks are designed.

Following the non-critical alert transmitted by the Salem HBD, NS standard operating procedures required the employee staffing the Wayside Help Desk to monitor the L1 bearing as it traversed additional detectors and to determine whether the temperature trend required further action. However, the distance between the HBDs and the speed of bearing degradation were such that, by the time the train reached the next HBD, about 19 miles away in East Palestine, the L1 bearing was already failing. Its exterior temperature measurement had reached at least 253°F, more than 50°F above the critical bearing alarm threshold. The Wayside Help Desk

¹¹⁷ NTSB Investigative Hearing Transcript, Day 2, pp. 219-20.

procedures did not create an opportunity to notify the crew of a problem before the East Palestine HBD broadcast a critical alarm. The bearing separated less than a minute later, as the crew began to stop the train. The NTSB concludes that the combination of NS standard operating procedures that required only continued monitoring for non-critical bearing alerts, the limited ability of HBDs to measure a bearing's actual internal temperature, and the distance between detectors did not give the train's crew adequate warning to stop the train before the suspect bearing failed and caused the derailment.

At the NTSB's Investigative Hearing, the NS Assistant Vice President of Signals and Communications testified that NS based its alert and alarm temperature thresholds on its own experience with HBDs and AAR standards.¹¹⁸ However, as the AAR Senior Vice President of Safety and Operations testified, the AAR definition of an overheated bearing is based on what makes a railcar repair billable to the railcar owner or lessor, and railroads choose their own temperature thresholds and operating procedures based on their experience balancing between preventing bearing failures and avoiding unnecessary stops.¹¹⁹ It is unclear whether the AAR definition of an overheated bearing is an appropriate temperature threshold for a wayside defect detection system intended to prevent accidents, especially when some current detector technologies—such as the HBDs relevant to the East Palestine derailment—may not accurately measure a bearing's maximum temperature.

To determine whether NS's use of wayside bearing defect detectors was representative of general industry practice, the NTSB requested information from all the Class I railroads about their use of wayside bearing defect detectors. All six Class I railroads responded, and the results are summarized in table 7. All six Class I railroads reported using HBDs and ABDs, but they varied in alarm criteria, wayside equipment inspection and maintenance intervals, detector spacing, and plans for future deployments of HBDs and ABDs. The available information also described HBD deployment in terms of "average" spacing between detectors, which may mask additional variation. Depending on the exact locations of the HBDs, the average spacing may not be the typical spacing, and the maximum distance between HBDs may differ dramatically from the average. In the East Palestine derailment, the three HBDs of interest were an average of about 15 miles apart, but the interval between the Salem HBD and East Palestine HBD was about 19 miles, and the train derailed while traversing the East Palestine HBD. The maximum distance between detectors is

¹¹⁸ NTSB Investigative Hearing Transcript, Day 2, pp. 211-13.

¹¹⁹ NTSB Investigative Hearing Transcript, Day 2, pp. 215-16.

therefore a useful metric in evaluating wayside bearing defect detection systems, but the current typical maximum is unclear.

The AAR does have recommended practices for HBD installation on key routes in its Circular OT-55-R, which specifies wayside defect detector spacing of 40 miles or less or “an equivalent level of protection based on improvements in technology” (AAR 2024a). However, the HBDs traversed by train 32N shortly before the derailment met this criterion, and the bearing that led to the derailment went from below the alert threshold to separated in about 30 miles. Further, this maximum applies only to key routes, and the option to install an “equivalent level of protection” invites the question of what level of protection a 40-mile maximum spacing provides compared to alternatives.

The NTSB acknowledges the positive impact of proven technologies such as HBDs and the growing use of newer technologies such as ABDs. However, the variations in wayside detector alarm criteria, configurations, and maintenance indicate that the rail industry has not reached a consensus on the optimal use and upkeep of wayside bearing defect detection systems. An AAR definition of an “overheated bearing” exists, but it relates to billing for repairs, not directly to safety or wayside detection. As the East Palestine derailment demonstrates, the successful use of wayside bearing defect detection systems depends on how these systems are implemented, including alert and alarm criteria that provide train crews with an opportunity to respond to overheating bearings before they fail. The performance of the HBD in Sebring, Ohio, also illustrates the importance of understanding each detection technology’s limitations when planning and operating a wayside bearing defect detection system. Research into these subjects would provide a basis for a more informed approach to the use of bearing defect detection systems. The NTSB concludes that without research into how differences in alert and alarm thresholds and varied distances between detectors affect the performance of wayside bearing defect detection systems, railroads and regulators lack the information to determine what changes would produce significant safety improvements.

According to the database maintained by the FRA’s Office of Safety Analysis, 69 of the 896 FRA-reportable rail accidents (7.7%) attributed to mechanical or electrical failures from 2020 through 2023 were caused by overheated wheel

bearings, making overheated wheel bearings the single most common mechanical or electrical cause of accidents.¹²⁰ The accident count by year is summarized in table 15.

Table 15. Overheated bearing accidents by year.

Accident Type	2020	2021	2022	2023
All mechanical and electrical	234	204	245	213
Overheated journal bearing	17	21	11	20

Because overheated wheel bearings are the single most common mechanical cause of accidents, the NTSB is concerned by the lack of industry consensus on a minimum standard for system configurations and related practices, including alert and alarm thresholds and operating rules. Further, the NTSB has identified additional bearing defect detection technologies undergoing testing and development, such as railcar-mounted bearing defect detectors, that may not share limitations specific to HBDs (Tarawneh, Montalvo, and Wilson 2021; Pams et al. 2024). The FRA has experience in fostering railroads' development and adoption of advanced safety technology, notably PTC, and is positioned to identify ways of improving bearing defect detection. Therefore, the NTSB recommends that the FRA research the effectiveness of current bearing defect detection systems, identify minimum standards to protect railroad personnel and the public, and make public the results of this research. In addition to experience and expertise in working with industry partners, the FRA has the regulatory authority to set and enforce minimum safety requirements, and railroads must meet or exceed the level of safety provided by FRA regulations. The NTSB recommends that the FRA use the results of the research described in R-24-2 to develop and establish minimum requirements for bearing defect detection systems, including criteria for bearing alert and alarm thresholds and maximum distances between wayside detectors.

However, even appropriate alert and alarm criteria are insufficient to protect safety if no alert is transmitted because of technical issues or if railroads do not respond effectively to alerts and alarms. In the months after the East Palestine derailment, the NTSB investigated two accidents in which a train traversed an HBD

¹²⁰ (a) The database counts only journal bearings, the type involved in the East Palestine derailment. (b) The FRA database is searchable and accessible here: <https://safetydata.fra.dot.gov/OfficeofSafety/publicsite/Query/TrainAccidentsFYCYWithRates.aspx>. (c) *Mechanical and electrical* are treated as a single category in this database. For context, the next three most common causes were worn flanges (5.9%), broken or defective knuckles (4.8%), and missing coupler detainer pins or cross keys (3.5%).

that detected an overheating bearing, but the wayside bearing defect detection system did not prevent a derailment from occurring shortly afterward.

The first derailment occurred on May 10, 2023, when NS freight train 14M in New Castle, Pennsylvania, derailed about 45 minutes after starting to traverse an HBD.¹²¹ The HBD recorded a temperature of 253°F on the east-side bearing of the lead axle of the 164th railcar in the consist (line 167, a hopper car), a temperature high enough to trigger a critical alarm and critical alert, both of which require immediately stopping the train under NS operating rules. The NTSB reviewed radio transmission records and confirmed that the HBD transmitted a critical alarm. However, the NTSB's review of the locomotive data records showed that the alarm was not broadcast over the in-cab speakers, and the crew of train 14M was not warned that a bearing had overheated.¹²² The NTSB also reviewed the Wayside Help Desk data logs and found that the desk did not receive an alert about the overheated bearing.

The NTSB's on-scene examination of the HBD determined that during maintenance, two transducers—critical components of the HBD that enable it to detect passing trains and count axles—had been removed and replaced in the wrong positions. The incorrectly positioned transducers prevented the HBD from communicating information to the Wayside Help Desk in a way the system could interpret and display. Even though the HBD correctly identified an overheated bearing, a pair of communication failures (one related to the improperly replaced transducers, the other of unknown causes) prevented the wayside bearing defect detection system from warning the crew of train 14M of a failed bearing.

The New Castle derailment illustrates the importance of test and inspection procedures adequate to identify compromised detectors. Currently, these practices are unregulated; the FRA has published guidance on wayside detection systems, but it has stopped short of imposing requirements (FRA 2019). However, railroads rely on wayside bearing defect detection systems for safe operation—much like signal systems, which the FRA regulates under 49 *CFR* Parts 235 and 236. Unlike the regulations for signal systems, there are no specific regulations for wayside bearing defect detectors prescribing intervals or standards for installation, inspection, testing, calibration, or general maintenance. The NTSB concludes that regulatory

¹²¹ Visit [ntsb.gov](https://www.ntsb.gov) to find additional information in the [public docket](#) for this investigation (case number RRD23FR011).

¹²² Available evidence did not support a determination of why the alarm was not broadcast over the in-cab speakers.

requirements for the installation, inspection, and maintenance of wayside bearing defect detectors would protect the reliability of these devices and improve the safety of railroad operations. Therefore, the NTSB recommends that the FRA establish requirements for the installation, inspection, and maintenance of wayside bearing defect detectors to protect the reliability of these devices and improve the safety of railroad operations.

The NTSB also investigated the July 6, 2023, derailment of an NS coal train near Elliston, Virginia.¹²³ In this accident, an HBD broadcast a critical alarm for a bearing on the lead axle of a the 71st railcar (line number 74, a gondola car), indicating a measured temperature of at least 170°F above ambient. When interviewed by the NTSB, the crew described how they stopped the train, confirmed a hot bearing using a temperature indicator stick, and communicated this confirmation to the Wayside Help Desk.¹²⁴ The Wayside Help Desk analyst directed them to set out the railcar for inspection. A dispatcher authorized the crew to move the train about 13 miles to a siding before setting out the suspect railcar for inspection. The derailment occurred during this movement while the train was traveling about 25 mph.

As a result of this derailment, NS issued an operations bulletin imposing additional speed and distance limits on moving equipment with suspect bearings. These improvements are confined to NS, and as indicated by the NTSB's survey of Class I railroads, operational responses to bearing alerts and alarms significantly vary by railroad. No publicly available research exists to support comparison of these varied responses, evaluate their effectiveness, and drive continuing improvements. The NTSB concludes that because the effectiveness of wayside bearing defect detection systems depends on appropriate operational responses, and because the rail industry has yet to arrive at a consensus standard for these responses, research is necessary to determine what operational responses to bearing alerts and alarms are sufficient to prevent bearing-related accidents. The NTSB also recommends that the FRA use the results of the research described in R-24-2 to develop and establish rules governing railroads' operational responses to bearing alerts and alarms.

¹²³ Visit [ntsb.gov](https://www.ntsb.gov) to find additional information in the [public docket](#) for this investigation (case number RRD23FR013).

¹²⁴ A *temperature indicator stick* is made of material that melts instantly when the surface it is touching reaches a certain temperature—in this case, 169°F.

2.2.5 Accident Bearing Failure Analysis

Railcar bearings can fail in several ways. Research has found that age-related bearing failures are the most common and can result from spalling, uneven loading, and lubrication breakdown, while the rarer non-age-related failures typically result from loose components, high loading, and water ingress (Iwand 2021).¹²⁵

However, damage to the recovered components of the L1 bearing was too severe to allow laboratory determination of why the bearing burned off. Any traces of fatigue, loose components, loss of lubrication, water ingress, or other root causes that can eventually lead to bearing failure were erased by the high temperatures of the burn-off and subsequent fire exposure. While meteorological and CLM records indicate that the hopper car was subjected to severe weather in 2016 and 2017—including significant rainfall from Hurricane Harvey—the bearing continued in service for more than 5 years after Hurricane Harvey, and there is no evidence of the bearing showing signs of failure before the derailment sequence described in this report. The available evidence does not indicate that the bearing failed as a result of water ingress or a weather event, and the root cause of the bearing's failure remains unclear.

Lack of usable physical evidence following bearing burn-off is not an isolated problem. The NTSB also recovered burned-off bearing components during our investigation of the New Castle and Elliston derailments and found that both failed bearings had been reconditioned, but the components were too severely damaged to support laboratory determination of why either bearing burned off. The NTSB's investigations into the East Palestine, New Castle, and Elliston derailments all encountered the same general issue: a bearing failure significant enough to lead to an accident tends to destroy the evidence of its underlying cause. Testing has found that a bearing failure can happen rapidly; a bearing can go from below an alarm temperature to seized (no longer able to rotate as designed) in less than a minute (Leedham 1992). The accompanying increase in temperature is rapid enough that it is unlikely to be arrested in time to preserve useful forensic evidence about underlying causes even if the overheated bearing is detected and removed from service. Damaged bearings that remain in service long enough to burn off and cause a derailment are subjected to even more heat and friction. Examination of individual

¹²⁵ *Spalling* is the separation of flakes or chips of material, usually as a result of subsurface fatigue.

bearings after bearing-related accidents is unlikely to provide useful information about preventing or predicting bearing failures.

Lacking physical evidence from the bearings sufficient to determine why these three specific bearings burned off, the NTSB attempted to explore common factors across all three bearings: all were on freight cars, all were on lead axles, and all had been reconditioned. To establish a baseline for whether these factors influence bearing failure rates, a railroad, investigator, or regulator would need access to a database of detailed railcar bearing statistics. However, there is no current database that records bearing manufacturer, railcar type, mileage at failure, bearing position, new or reconditioned status, service type, and other factors that could plausibly affect bearing performance. Such a database would support efforts to identify trends in bearing failure and underlying commonalities. For example, a group of representatives of federal and state regulatory agencies and the natural gas and plastic pipe industries created The Plastic Pipe Database Committee, which maintains a database on the performance of plastic piping materials. The database is administered by the American Gas Association and is intended to support understanding of leak frequency and causes by collecting as much information as possible from a representative cross-section of the natural gas industry (Plastic Pipe Data Collection Committee 2015).

The NTSB is concerned that in the absence of comparable bearing data from across the rail industry, railroads, investigators, and regulators lack statistical baselines to help sort causally relevant factors from irrelevant ones. For example, all three burned-off bearings in the East Palestine, New Castle, and Elliston derailments were reconditioned. However, thousands of reconditioned railcar bearings operate without incident every day. Without additional information, railroads, investigators, and regulators cannot reliably identify factors of interest.

The practical difficulties of obtaining useful physical evidence from individual destroyed bearings invite two approaches to gathering more information about causes of bearing failure. First, consistent and detailed collection of information about bearings involved in accidents would, over time, allow investigators to identify common factors disproportionately represented in accident bearing failures (certain types of railcars or service, reconditioning, and maintenance intervals are plausible possibilities). Second, bearings replaced as part of scheduled maintenance or in response to early defect detection (such as by ABDs) provide opportunities to collect physical evidence or record background information regarding risk factors for unusual deterioration that could cause a bearing to fail sooner than expected. The NTSB concludes that a database capturing bearing failure and replacement information could help identify what factors pose an increased risk of burn-off so that

railroads, regulators, and investigators can better address bearing-related safety issues. The AAR already maintains a database of railcar billing records, which includes information about bearing replacements and supports industry research about bearing defects and defect detection. This database provides a starting point and potential model for future efforts. The NTSB recommends that the AAR develop a database of bearing failures and replacements and make it available to railroads, regulators, and investigators to help determine and address failure risk factors.

2.3 Early Emergency Response

The early emergency response at East Palestine focused on containing the fire, determining what hazardous material could have been released, protecting residents near the derailment site, and starting mitigation efforts for tank cars exposed to fire conditions. The EPFD and EPPD were the first agencies on the scene shortly after the derailment, about 9:00 p.m. on February 3, and the EPFD deputy fire chief served as incident commander for the first 5 hours of the response. After 11:00 p.m. on February 3, NS personnel and contractors arrived on the scene and began to provide expertise to emergency responders. About 2:00 a.m. on February 4, the EPFD fire chief assumed the incident commander role, and over the following days, response efforts shifted focus to the five derailed VCM tank cars.

The NTSB's investigation into the early emergency response identified safety issues with the initial deployment of firefighters, the transmittal of consist information, and the legibility of placards on hazardous materials tank cars.

2.3.1 Initial Deployment of Firefighters

The EPFD responded to 911 calls and reached the accident scene within 10 minutes of the derailment. During this stage of the emergency response, EPFD firefighters did not have access to the consist of train 32N but had observed tank cars among the derailed and burning equipment. The applicable guidance from the 2020 ERG was the "Mixed Load / Unidentified Cargo" entry for a fire involving tank cars, which advised a half-mile (or 2,640-foot) preliminary isolation and evacuation of the scene, noted the need for self-contained breathing apparatuses, and cautioned that materials may react violently with extinguishing agents, including water (PHMSA 2020). The entry recommended the use of water to cool containers but cautions against allowing water to enter those containers.

The EPFD deputy fire chief set up a command post at a business about 400 feet from the burning train, more than 2,000 feet inside the ERG-recommended

isolation and evacuation zone. Without referencing the 2020 ERG, volunteer firefighters approached the pileup and began applying water to contain the fire, which grew rapidly. Firefighters were equipped with self-contained breathing apparatuses, but without more information about the train's consist, the incident commander had no way of determining whether this personal protective equipment was adequate for operations within the half-mile isolation zone. The NTSB concludes that, while the EPFD deputy fire chief and other volunteer firefighters acted in good faith to protect their community, the initial emergency response did not conform to ERG guidance for fires involving tank cars and unknown materials; both the proximity of the first command post to the fire and the use of manned hoses near a fire involving unknown materials placed these firefighters at unnecessary risk.

Pre-certification volunteer firefighter training in Ohio is limited by statute under State of Ohio Revised Code Section 4765.55. A training course for a Volunteer Firefighter certificate may not exceed 36 hours. According to guidance distributed by Ohio EMS, the foundational volunteer firefighter course does not permit participation in training involving hazardous environments because of this time constraint (Ohio EMS 2023). The basic 36-hour training course does not meet the NFPA 1010 standard for professional firefighters (or the NFPA 1001 standard in place at the time of the derailment), which requires a minimum of 160 hours of training and includes job performance requirements not addressed in the volunteer course. Fire chiefs or authorities having jurisdiction are responsible for providing additional training for volunteer firefighters expected to operate in hazardous environments. However, the statute does not specify minimum standards, specific courses, or demonstration of skills or knowledge to ensure that additional training adequately prepares firefighters for hazardous environments. The EPFD deputy fire chief had completed two additional courses in hazardous materials awareness and operations in 2022, but the response in East Palestine still deviated from recommended practices by placing firefighters near burning tank cars and establishing a command post a few hundred feet from a fire involving unknown hazardous materials.

Statutory requirements and training courses for professional firefighters in Ohio meet the relevant NFPA 1010 standard. However, the NTSB is concerned that volunteer fire departments in the state of Ohio are called on to respond to the same incidents as their professional counterparts, as seen in this accident, but that volunteers may have only a fraction of the training Ohio requires for professional firefighters: 36 hours instead of at least 160 hours. Further, the Ohio statute significantly limits initial training for volunteers and has resulted in a prohibition on training in hazardous environments. While the statute instructs local authorities to provide additional training, it establishes no clear requirements or guidance on what

additional training is appropriate. The EPFD personnel who responded to the derailment and fire had varying training levels related to hazardous materials that ranged from no training at all to technician-level training, but the NTSB has not found evidence that their roles in the initial emergency response were tailored to their individual training levels. The NTSB concludes that the state of Ohio's statutory requirements for volunteer firefighter training were insufficient to support a safe emergency response to the East Palestine derailment led by a volunteer fire department. Therefore, the NTSB recommends that the state of Ohio amend its firefighter training statute and revise its volunteer firefighter certification standards to meet the NFPA 1010 standard for professional firefighters.

The National Volunteer Fire Council (NVFC) represents the interests of the volunteer fire, EMS, and rescue services. The International Association of Fire Chiefs (IAFC) represents the interests of emergency responders with a focus on leaders. The International Association of Fire Fighters (IAFF) is a labor union representing firefighters, emergency medical workers, and rescue workers in the United States and Canada.¹²⁶ These organizations provide resources, programs, education, and advocacy for emergency responders and are positioned to encourage adoption of standards to protect their members' safety, including identifying trainings and sources of funding. Thus, the NTSB recommends that the NVFC, IAFC, and IAFF advise their members of the circumstances of the East Palestine derailment and fire, identify fire departments whose personnel are not trained to the NFPA 1010 standard for professional firefighters, recommend that these departments adopt training that meets this standard, and inform them of funded training opportunities available through private, state, and federal programs. The NTSB also recommends that the NVFC identify barriers to adequate fire and emergency response training for volunteer firefighters, particularly for situations where hazardous materials are present, and publish actions states, municipalities, and the private sector can take to provide the flexibility necessary for volunteer firefighters to obtain training.

2.3.2 Communication and Consist Information

The NS Cleveland East dispatcher confirmed that the crew of train 32N had experienced an emergency about 8:56 p.m. Emergency responders made their first request for consist information about 9:04 p.m. by calling the NS dispatch center in Atlanta, Georgia, which did not provide the requested information at that time. Consist information did not reach emergency responders until shortly before

¹²⁶ Further information is available on these organizations' websites, accessible at <https://www.nvfc.org/about/>, <https://www.iafc.org/>, and <https://www.iaff.org/>.

10:00 p.m., when the NS regional hazardous materials manager emailed the consist to the CCEMA director while driving to the scene. About the same time, phone calls were taking place between NS personnel, the EPFD fire chief, and the incident commander. Through these calls, the incident commander became aware of two hazardous materials in the consist: benzene and VCM. After 10:00 p.m., consist information spread piecemeal through responding agencies and personnel. In interviews with the NTSB, emergency responders reported issues with radio interoperability and characterized the overall incident command as fractured or chaotic. Not until about 11:00 p.m., at the recommendation of the Ohio State Patrol, did the EPFD deputy fire chief, acting as the incident commander, issue a 1-mile evacuation—the distance recommended by the 2020 ERG for fires involving tank cars transporting VCM or isobutylene.¹²⁷ About the same time, NS personnel and contractors began arriving on the scene and recommending that firefighters redeploy to safer distances. Firefighters suspended fire suppression activities and relocated to safer positions around midnight on February 4. As part of the movement to safer locations, the deputy fire chief moved the command post to the combined police and fire station about a mile from the derailment site.

The emergency response effort involved many agencies from multiple jurisdictions and three states. The two hazardous materials teams dispatched to the scene—the East Liverpool and Beaver County teams—were unable to establish radio communications with the incident commander or other EPFD personnel, and concerns about radio communication led the Beaver County director of emergency services to share hazardous materials information with Beaver County fire departments directly in the expectation that radio issues might otherwise prevent them from receiving that information. The East Liverpool fire chief addressed the lack of radio interoperability by assigning personnel from his own team to stay in the command post so that his radio communications could reach other personnel stationed there.

These approaches to overcoming lack of interoperability reflect ingenuity and awareness of risk in the face of a challenging situation. However, reliance on face-to-face communications and lack of common channels to support interoperability reduce the efficiency of information sharing. The NTSB concludes that because there were not common radio channels between all responding agencies, the emergency response lacked efficient coordination.

¹²⁷ Neither VCM nor isobutylene had been released at this time. The ERG guidance applies to a fire involving tank cars carrying these materials; the recommended isolation and evacuation distances apply even if material is not being released or fueling the fire.

Interoperability is a goal set by the 2019 NECP, the national roadmap for ensuring effective communications under NIMS. The standards and methods described in the 2019 NECP and integrated into the overall NIMS doctrine remain the preferred approach to ensuring efficient, effective communication between emergency responders, and the fundamentals of interoperability are addressed in the associated training courses. CISA maintains a regularly updated list of federal financial assistance programs intended to support investment in emergency communications.¹²⁸

The NTSB is concerned that complete and accurate consist information was not quickly and clearly communicated to the incident command after East Palestine dispatch contacted NS by phone and requested it. The slow provision of consist information to a single point of contact, followed by partial information provided over the phone to the incident commander, and then the slow distribution among responding agencies, delayed the evacuation to the ERG-recommended distance and protracted the time firefighters spent responding to an unknown set of hazards. Slow transmittal and distribution also delayed the Ohio State Patrol's recommendation to the incident commander that the shelter-in-place order be replaced by an evacuation, the response recommended in the 2020 ERG. The NTSB concludes that the delayed transmittal of consist information by NS to emergency responders needlessly increased the time emergency responders spent near the derailment pileup and delayed the evacuation order, resulting in unnecessary and increased exposure of emergency responders and the public to postderailment hazards.

In response to this accident, NS began integrating its emergency response notification process with RapidSOS, a digital platform designed to provide emergency responders with real-time consist information and notify NS of 911 calls reporting track emergencies in NS's rail network. This change is intended to make consist information available to first responders sooner and allow NS to begin responding to emergencies as soon as 911 calls are made. However, these changes may not address the specific problem present at East Palestine: an incoming request for information from a dispatch center remaining unanswered. The NTSB recommends that NS review and revise its procedures to immediately provide emergency responders with an accurate copy of the train consist upon becoming aware of an accident. The NTSB recommends that CCEMA adopt a policy to, upon receipt of a train consist, immediately provide it to the incident commander and all

¹²⁸ The complete list is available here:
<https://www.cisa.gov/safecom/emergency-comms-grants-list>.

appropriate response agencies and departments. The NTSB also recommends that CCEMA update its Emergency Operations Plan, Hazardous Materials Response Plan, and Hazard Mitigation Plan, as appropriate, with lessons learned from the East Palestine derailment and fire, including, at a minimum, coordination among response agencies, communications, requests for and distribution of the train consist, staging and availability of equipment and other resources, and training for emergency responders.

The NTSB has investigated other accidents involving consist availability, including the July 10, 2005, collision and derailment of two Canadian National Railway Company freight trains in Anding, Mississippi, that resulted in four train crewmember fatalities, the release of 15,000 gallons of diesel fuel that burned for about 15 hours, and the evacuation of 100 residents (NTSB 2007). Seven tank cars containing hazardous materials residue derailed. The NTSB found that the railroad did not have the capability to provide first responders with consist information for one of the trains after the on-board copy was destroyed, and that this prevented emergency responders from promptly identifying the hazardous materials involved. The NTSB recommended that PHMSA:

With the assistance of the Federal Railroad Administration, require that railroads immediately provide to emergency responders accurate, real-time information regarding the identity and location of all hazardous materials on a train. (R-07-4)¹²⁹

On January 22, 2008, in a response to Safety Recommendation R-07-4, PHMSA indicated to the NTSB that it was examining (1) ways to improve the availability of accurate and immediate information for emergency responders on the scene of an accident and (2) strategies for enhancing emergency response planning and training efforts. Additionally, PHMSA indicated that it was evaluating the emergency response issues raised in the safety recommendation and the federal, state, and local government and industry programs intended to address those issues. Based on PHMSA's communications, the NTSB classified Safety Recommendation R-07-4 Open–Acceptable Response.

On March 2, 2012, we reiterated Safety Recommendation R-07-4 as a result of our investigation of the June 19, 2009, derailment of a Canadian National Railway

¹²⁹ Safety Recommendation R-07-4 is currently classified Open–Unacceptable Response.

Company ethanol unit train in Cherry Valley, Illinois (NTSB 2012b).¹³⁰ Our investigation determined that the original consist for the train had only 3 of the 76 cars in their proper positions. Because this was a unit train, all loaded tank cars were transporting ethanol. We found that:

The inaccurate train consist carried by the crew did not affect the emergency response to this accident; however, had a mixture of hazardous commodities been involved, the inaccurate consist information could have hampered the response effort or put the safety of emergency responders and others at risk. (NTSB 2012b)

On September 6, 2013, PHMSA published an advance notice of proposed rulemaking, titled "Hazardous Materials: Rail Petitions and Recommendations to Improve the Safety of Railroad Tank Car Transportation" (78 Fed. Reg. 54849). In our December 5, 2013, response, we noted our ongoing investigation of the November 30, 2012, derailment of a Conrail freight train that released VCM in Paulsboro, New Jersey. The NTSB convened an Investigative Hearing on July 9-10, 2013, where emergency responders testified that their response actions were hindered by the lack of timely and accurate train consist information. Noting both the positive steps proposed by PHMSA and this hearing testimony, we commented:

However, we are very disappointed that Safety Recommendation R-07-4 has remained open for more than 5 years. The NTSB is encouraged by the PHMSA Hazardous Materials Automated Cargo Communications for Efficient and Safe Shipments program (HM-ACCESS) and notes that PHMSA has instituted a paperless hazard communication pilot program to evaluate the feasibility and effectiveness of paperless electronic communication systems. Pending completion of the recommended action, the NTSB has classified Safety Recommendation R-07-4 "Open-Acceptable Response."

In our investigation of the Paulsboro derailment, we determined that the train consist and ERI were not provided to the incident command for more than 3 hours (NTSB 2014c). In our investigative report, we found that:

During the early hours following the accident, Consolidated Rail Corporation personnel did not immediately provide critical hazardous

¹³⁰ (a) A *unit train* is a train transporting a single commodity. (b) Other aspects of this accident are discussed in more detail in section 2.4.2.2.

materials information to emergency responders that could have assisted in executing a safer response to this accident. (NTSB 2014c).

We therefore reiterated Safety Recommendation R-07-4. In our August 26, 2014, letter to PHMSA, we noted that we believed available technologies could and should be used to supplement the paper-based train consist for improving the dissemination of chemical hazard information to emergency responders.

On May 23, 2023, we sent a letter to PHMSA regarding the lack of an NPRM or final rule requiring real-time consist notifications and observing that other than a January 19, 2017, advance notice of proposed rulemaking that had not led to a final rule, PHMSA had not taken action to address Safety Recommendation R-07-4 (82 Fed. Reg. 6451). We therefore classified Safety Recommendation R-07-4 Open–Unacceptable Response.

On June 27, 2023, partially in response to this safety recommendation and following the East Palestine derailment, PHMSA issued an NPRM titled “Hazardous Materials: FAST Act Requirements for Real-Time Train Consist Information,” proposing amendments to its rules for hazard communication. The proposed rule would require Class I railroads to promptly provide consist information to nearby emergency responders in the event of a release or suspected release of hazardous materials.

On August 23, 2023, the NTSB commented on the proposed rule.¹³¹ While pleased to see this NPRM, we noted three concerns: the proposed rule does not define “promptly”; notification depends on “the release or suspected release” of hazardous materials, not only an accident or incident involving a train carrying hazardous materials; and one version of the proposed rule would apply only to Class I railroads. Waiting to determine whether a release is “suspected” rather than merely possible could slow consist notification. Further, non-Class I railroads can experience hazardous materials releases. For example, the NTSB investigated a release involving a Class II railroad in June 2023 in Reed Point, Montana, when a Montana Rail Link freight train derailed 15 hazardous materials tank cars and released hazardous materials (molten sulfur and asphalt petroleum liquid) into the Yellowstone River.¹³²

¹³¹ The full text of the NTSB’s comments is available here: <https://www.regulations.gov/comment/PHMSA-2016-0015-0023>.

¹³² For more information about this accident, refer to the docket for this investigation: <https://data.ntsb.gov/Docket/?NTSBNumber=HMD23LR002>.

On June 24, 2024, PHMSA published Final Rule HM-263, Hazardous Materials: FAST Act Requirements for Real-Time Train Consist Information, requiring that any Class I or II railroad transporting hazardous materials immediately contact the local PSAP and provide consist information when a train carrying hazardous materials is involved in an accident that will require a response from local response agencies (81 Fed. Reg. 52926). The final rule specifies that the consist information must be provided electronically in a form the PSAP can readily access. Class III railroads must either follow the same requirements as other railroads or develop their own plans for alternative means of providing consist information to local PSAPs or emergency response agencies. If using an alternative means, Class III railroads must prepare written plans and conduct annual tests to demonstrate that their plans are effective. Class I railroads have 1 year to comply with the new rule; Class II and III railroads have 2 years to comply.

We recognize that PHMSA has addressed the concerns we identified in our NPRM comments by creating a final rule that requires immediate consist notification following an accident, addresses all rail accidents involving hazardous materials trains that affect local response agencies, and applies to all railroads that transport hazardous materials. The NTSB concludes that PHMSA's Hazardous Materials: FAST Act Requirements for Real-Time Train Consist Information addresses the safety concerns of Safety Recommendation R-07-4. The NTSB therefore classifies Safety Recommendation R-07-4 as Closed–Acceptable Action.

2.3.3 Placard Legibility

When a shipping name or identification number cannot be associated with a tank car or other package during an emergency response, the 2024 ERG (like the 2020 ERG current at the time of the East Palestine derailment) recommends reading the placards from a safe distance to determine what protective measures are appropriate (PHMSA 2024). Under 49 *CFR* 172.519, placards must be capable of withstanding 30 days of exposure to open weather conditions without deterioration or a substantial reduction in effectiveness. The performance standard does not address derailments or fires—circumstances under which emergency responders may need to use placards as instructed by the 2024 ERG.

The derailment of train 32N produced a derailment footprint about 1,200 feet long and comprising a mixture of hazardous and non-hazardous materials tank cars. Even with access to consist information, distinguishing which tank cars contained hazardous materials depended on the legibility of tank car markings, placarding, or accurate assessment of a tank car's original line number. Because the derailment

displaced tank cars from their original order and damaged or obscured markings, placards were the best option for responders to identify hazardous materials and appropriate protective measures. However, as the deputy fire chief reported in interviews with the NTSB, responding firefighters found that placards had been destroyed by fire and could not aid efforts to identify hazardous materials present at the scene. Firefighters continued to operate close to the derailment pileup and fires until NS personnel and contractors advised them to withdraw to a safer distance. Therefore, the NTSB concludes that the vulnerability of tank car placards to fire exposure resulted in illegible placards and hampered emergency responders' efforts to identify hazards. Current federal requirements for placards address normal transportation conditions but do not account for placard survivability during derailments or fire exposure. The requirements for survivability therefore do not adequately account for events where placards may be the sole immediate source of hazard information and will be subjected to fire or other sources of damage. The 2024 ERG notes that this scenario is possible, and it occurred at East Palestine. Placarding requirements should include survivability sufficient to ensure that placards are usable by emergency responders during rail and other transportation emergencies. The NTSB is aware of placard designs, such as placards cut from steel, likely to offer improved survivability under accident conditions compared to tagboard or plastic. The NTSB recommends that PHMSA require that placards be able to survive fires and accidents and remain legible during such emergencies long enough to fulfill their functions as described in the ERG.

2.4 Tank Car Derailment Performance

The derailment involved 27 tank cars of four specifications: DOT-111, AAR-211, DOT-105, and DOT-117. During the derailment and subsequent fire, three DOT-111 tank cars released hazardous materials: ethylene glycol monobutyl ether, 2-ethylhexyl acrylate, and butyl acrylates. During the same period, five DOT-111 tank cars and one AAR-211 tank car released non-hazardous materials: propylene glycol, petroleum lubricating oil, and diethylene glycol.

None of the three DOT-117 tank cars that derailed sustained breaches or released lading during the derailment or emergency response.

Of the six DOT-105 tanks involved in the derailment, one (a tank car transporting isobutylene) did not release lading, was not involved in the vent and burn, and was later transloaded; it was not breached during the derailment or at any time during the emergency response. Postaccident examinations of the five derailed DOT-105 tank cars carrying VCM identified no evidence of impact damage

penetrating into the tank shells. While relative speeds and chaotic movements leading to impacts between railcars cannot be predicted with certainty, the derailment speed itself exceeded the performance standard for tank head puncture resistance systems mandated in 49 *CFR* 179.16, which requires that head shields be capable of withstanding coupler impacts at relative speeds of 18 mph. FRA research has found that a loaded and constrained DOT-105 car constructed of TC128 grade B steel would likely puncture when impacted in its shell mid-section (an area not protected by the head shield) by a coupler-sized object at 14.5–17 mph (FRA 2018).¹³³ Despite the speed and energies involved in this derailment, the impact damages did not significantly challenge the lading retention capability of the DOT-105 tank cars. Postaccident examinations also identified no evidence of thermal tears.

During exposure to fires in the hours following the derailment, four DOT-105 tank cars released VCM through operation of their PRDs. Days after the derailment, on February 6, these four and one additional DOT-105 released more VCM through intentional breaching during a vent and burn procedure, which will be discussed further in section 2.5. Breaching damage for hazardous materials tank cars is summarized in table 16 (see also section 1.7.2).

Table 16. Summary of breaching damage to hazardous materials tank cars.

Line Number	Tank Car	Specification	Commodity	Amount Released	Primary Source of Release
28	TILX402025	DOT-105	VCM	Entire load	Vent and burn
29	OCPX80235	DOT-105	VCM	Entire load	PRD release, vent and burn
30	OCPX80179	DOT-105	VCM	Entire load	PRD release, vent and burn
31	GATX95098	DOT-105	VCM	Entire load	PRD release, vent and burn
36	SHPX211226	DOT-111	Ethylene glycol monobutyl ether	Entire load	Tank head crack, BOV fully open
38	DOWX73168	DOT-111	2-ethylhexyl acrylate	Partial load	Tank head cracks, tank head puncture
50	UTLX205907	DOT-111	Butyl acrylates	Entire load	Tank head punctures, manway gasket burned away
55	OCPX80370	DOT-105	VCM	Entire load	PRD release, vent and burn

¹³³ In the associated testing, the tank shell was struck by a 297,000-pound ram car equipped with a 12-inch by 12-inch impactor.

2.4.1 Sources of Released Material

Postderailment examinations of tank cars identified three main sources of released lading: mechanical breaches sustained during the derailment, releases through PRDs, and the vent and burn procedure.

Of the 16 DOT-111 tank cars that derailed, 7 sustained mechanical breaches: 3 hazardous materials tank cars and 4 non-hazardous materials tank cars. One additional non-hazardous material DOT-111 tank car released lading through its top fittings. It is unclear whether the top fittings were compromised by mechanical damage or fire exposure. One of the two AAR-211 tank cars also lost lading, but the source of the release was not reported to the NTSB.¹³⁴ Neither AAR-211 tank car was carrying hazardous materials.

The fires eventually involved a variety of ladings and cargos. The first material to ignite was likely butyl acrylates, a Class 3 flammable liquid, released from DOT-111 tank car UTLX205907.¹³⁵ Butyl acrylates have a lower flash point (104°F) than any other released material, and the tank likely released its lading rapidly because of large tank head punctures. (See figure 20.) The large pool fire that burned for 2-3 hours in the ditch along the length of the derailment site was likely fueled by butyl acrylates.

The two mechanically breached DOT-111 tank cars transporting combustible liquids (SHPX211226 carrying ethylene glycol monobutyl ether and DOWX73168 carrying 2-ethylhexyl acrylate) are less probable candidates for the fire originator because of their ladings' higher flash points (144°F and 187°F, respectively). These tank cars still presented a greater fire risk than the other mechanically breached tank cars, all of which were carrying liquids that were less likely to produce flammable vapor or had flash points too high to be classified as hazardous materials. Therefore, the NTSB concludes that the postderailment fire likely began with hazardous material released from a mechanically breached DOT-111 tank car, most probably the butyl acrylates released from tank car UTLX205907.

The initial 2- to 3-hour pool fire led to additional fires involving released lading and various freight car commodities such as plastic pellets. These fires exposed

¹³⁴ The AAR-211 is generally similar to the DOT-111. Refer to section 1.7.1 for further detail.

¹³⁵ A derailment provides numerous potential ignition sources, such as sparks between colliding railcars. The available evidence did not indicate a specific ignition source for this accident.

derailed VCM tank cars to heat, and four of these tank cars released lading through PRD operation as a result of fire exposure.

On February 6, after NS and its contractors told the rest of the incident command that the heated VCM could undergo exothermic polymerization and cause a BLEVE, the incident commander approved a vent and burn procedure that released and ignited the VCM remaining in all five derailed VCM tank cars. The sequence of events that led to the incident commander's decision to vent and burn therefore began with a pool fire initiated by hazardous materials released from at least one mechanically breached DOT-111 tank car. The NTSB concludes that if DOT-111 tank cars transporting combustible and flammable liquids had not sustained mechanical breaches during the derailment, the DOT-105 tank cars transporting VCM likely would not have been exposed to the fire conditions that led to concerns about polymerization and ultimately the vent and burn actions that released additional lading from those five DOT-105 tank cars.

2.4.2 Non-Pressure Tank Cars

2.4.2.1 DOT-111 Derailment Performance at East Palestine

The DOT-111 and DOT-117 specifications are both non-pressure tank cars in widespread hazardous materials service, and the East Palestine derailment involved both specifications. Postderailment examination of the seven mechanically breached DOT-111 tank cars found that five sustained cracks or punctures in tank heads. This type of damage is consistent with impacts to the tank heads, usually between adjacent railcars as railcars' kinetic energy causes them to collide end-to-end (run-in) and leave the track (create a pileup) during a derailment. This indicates that the single most common failure mode for DOT-111 tank cars in East Palestine was tank head protection insufficient to preserve tank integrity. The DOT-117 tank cars subjected to the same derailment were equipped with full-height head shields and remained mechanically intact, underscoring the greater relative vulnerability of the DOT-111 tank cars to mechanical breaches.

2.4.2.2 Past DOT-111 Derailment Performance and Regulatory Action

The DOT-111 specification's vulnerability to breaches during derailments is a well-documented issue. The NTSB calculated release rates for DOT-111 tank cars in a 1991 safety study titled Transport of Hazardous Materials by Rail. The studied period extended from March 1988 through February 1989 and included 45 rail accidents involving 149 tank cars. The study found that 54% of DOT-111 tank cars involved in accidents in 1988-1989 released lading, and that head and shell punctures

accounted for 22% of releases (NTSB 1991). The NTSB observed a similar breach rate at East Palestine: the mechanical and thermal crashworthiness performance of DOT-111 tank cars in East Palestine represents a breach rate of 50% (8 of 16 derailed DOT-111s released lading), and a breach rate of 44% from confirmed mechanical damage.

Hazardous materials releases from DOT-111 tank cars have led to several investigations, safety recommendations, and regulatory actions. On June 19, 2009, Canadian National Railway Company ethanol unit train U70691-18 derailed in Cherry Valley, Illinois (NTSB 2012b). Of the 19 DOT-111 tank cars that derailed, 13 were breached and caught fire, resulting in the release of about 324,000 gallons of ethanol. The postderailment fire resulted in one death, nine injuries, and the evacuation of 600 homes within half a mile of the accident. The NTSB found that the inadequate design of the DOT-111 tank cars contributed to the severity of the accident. The NTSB determined that if enhanced tank head and shell puncture-resistance systems such as head shields, tank jackets, and increased shell thicknesses had been features of the DOT-111 tank cars involved in this accident, the release of hazardous materials likely would have been significantly reduced.

As a result of our investigation of the Cherry Valley derailment and fire, the NTSB issued the following safety recommendations to PHMSA:

Require that all newly manufactured and existing general service tank cars authorized for transportation of denatured fuel ethanol and crude oil in Packing Groups I and II have enhanced tank head and shell puncture-resistance systems and top fittings protection that exceeds existing design requirements for DOT-111 tank cars. (R-12-5)¹³⁶

Require that all bottom outlet valves used on newly manufactured and existing non-pressure tank cars are designed to remain closed during accidents in which the valve and operating handle are subjected to impact forces. (R-12-6)¹³⁷

The NTSB classified Safety Recommendations R-12-5 and R-12-6 Closed–Acceptable Action on July 12, 2016, after PHMSA’s adoption of final rule HM-251, which established the DOT-117 specification and required that tank cars in Class 3 flammable liquids service meet the associated standards if used in HHFTs.

¹³⁶ Safety Recommendation R-12-5 is currently classified Closed–Acceptable Action.

¹³⁷ Safety Recommendation R-12-6 is currently classified Closed–Acceptable Action.

The DOT-117 specification included the protective features described in the safety recommendations, and we noted in our letter to PHMSA that we commended the decision to require the DOT-117 specification for all Class 3 flammable liquids being transported in HHFTs, not only ethanol and crude oil.

On July 5, 2013, a Montreal Maine and Atlantic freight train with 72 DOT-111 tank cars carrying petroleum crude oil derailed in Lac-Mégantic Quebec, Canada (TSB 2014b).¹³⁸ Following a crew change, the train was left unattended on the mainline track. The train began to move uncontrolled on a descending grade, derailling 63 tank cars that released 1.6 million gallons of crude oil that ignited and killed 47 people.

The NTSB issued safety recommendations derived from its participation in the Transportation Safety Board of Canada's (TSB) investigation. Because the Cherry Valley recommendations regarding DOT-111 were recent and still open, our recommendations following Lac-Mégantic addressed safety issues other than the low survivability of DOT-111 tank cars. However, in safety recommendation letters addressed to PHMSA and the FRA, the NTSB noted the potential destructive effects of large numbers of derailed DOT-111 tank cars containing flammable materials and referenced other relevant NTSB investigations, including:

- The July 11, 2012, NS train derailment in a Columbus, Ohio, industrial area, in which three derailed DOT-111 tank cars released about 53,000 gallons of ethanol, with energetic rupture of one tank car in a postderailment fire (NTSB 2014b).
- The October 7, 2011, derailment of an Iowa Interstate Railroad train in Tiskilwa, Illinois, of 10 DOT-111 tank cars, resulting in fire, energetic rupture of several tank cars, and the release of 162,000 gallons of ethanol (NTSB 2013a).
- The October 20, 2006, NS ethanol unit train derailment in New Brighton, Pennsylvania, in which 23 DOT-111 tank cars derailed, fell from a bridge, caught fire, and released more than 485,000 gallons of ethanol (NTSB 2008).

On December 30, 2013, a westbound BNSF Railway train derailed 13 railcars transporting grain in Casselton, North Dakota, fouling the adjacent main track (NTSB 2017d). An eastbound BNSF Railway train with 104 tank cars loaded with petroleum crude oil struck a derailed railcar. The collision derailed 20 DOT-111 tank cars from

¹³⁸ The Transportation Safety Board of Canada (TSB) granted the NTSB observer status on the investigation.

the eastbound train; 18 tank cars were breached and released about 476,000 gallons of crude oil that subsequently caught fire. DOT-111 tank cars that released lading included 13 with torn or punctured heads and shells, 3 with thermal tears, 10 with damaged valves and fittings, and 3 that released product from BOVs. The investigation noted that the release was made more severe by the pooling of a flammable liquid that caught fire and caused additional tank cars to fail.

The NTSB adopted its report for Casselton on February 7, 2017, and released it on March 9, 2017, but because another NTSB derailment investigation involving DOT-111 tank cars led to urgent recommendations before the Casselton investigation was complete, the Casselton report classified existing safety recommendations relevant to the DOT-111 specification instead of issuing new ones. This additional investigation concerned the February 16, 2015, derailment of 27 loaded DOT-111 tank cars from a CSX Transportation crude oil unit train in Mount Carbon, West Virginia.¹³⁹ The tank cars were constructed to the CPC-1232 standard, but none had thermal protection. During the derailment, two tank cars were punctured and released more than 50,000 gallons of crude oil. Nineteen tank cars became involved in a postderailment pool fire that caused thermal tank shell failures on 13 tank cars that had otherwise survived the derailment. During our investigation, the NTSB collected information about three additional derailments in which 15 other CPC-1232 thermally failed and released thousands of gallons of flammable crude oil.¹⁴⁰

The NTSB noted that the DOT-111 tank cars (including those manufactured to the CPC-1232 standard) were not required to be equipped with thermal protection systems to protect the tank from exposure to pool or torch fire conditions. In our recommendation letter to PHMSA, the NTSB concluded:

The thermal performance and pressure relief capacity of bare steel tank cars that conform to current federal and industry requirements is

¹³⁹ The NTSB did not issue a separate final report for the Mount Carbon investigation. The associated docket is available at DCA15FR005.

¹⁴⁰ The three reviewed accidents included the February 14, 2015, derailment of a Canadian National Railway Company crude oil unit train that derailed 29 tank cars in a remote area near Gogama, Ontario (TSB 2017b); the March 5, 2015, derailment of a BNSF Railway crude oil unit train that derailed 21 CPC-1232 tank cars south of Galena, Illinois (FRA 2015); and the March 7, 2015, derailment of a Canadian National Railway Company crude oil unit train that derailed 39 CPC-1232 cars near Gogama, Ontario (TSB 2017a).

insufficient to prevent tank failures from pool fire thermal exposure and the resulting overpressurization.

As the result of our investigation, the NTSB issued urgent safety recommendations to PHMSA:

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. (R-15-14, Urgent)¹⁴¹

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. (R-15-15, Urgent)¹⁴²

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. (R-15-16, Urgent)¹⁴³

PHMSA published final rule HM-251 before publication of the NTSB's report on the Casselton derailment. Final rule HM-251 created the DOT-117 specification, which includes thermal performance standards, and required the specification's use

¹⁴¹ Safety Recommendation R-15-14 is currently classified Closed–Acceptable Action.

¹⁴² Safety Recommendation R-15-15 is currently classified Closed–Acceptable Action.

¹⁴³ (a) Safety Recommendation R-15-16 is currently classified Closed–No Longer Applicable. (b) The NTSB issued a fourth urgent safety recommendation, R-15-17, to support monitoring the replacement or retrofitting of tank cars. This safety recommendation (currently classified Closed–Acceptable Alternate Action) is less relevant to the current state of the DOT-111 phase out and is omitted from the discussion for brevity.

in HHFTs. However, as the NTSB noted in its letter to PHMSA on July 12, 2016, the final rule did not require thermal protection systems or PRDs on all tank cars in Class 3 flammable liquids service—only tank cars used in HHFTs. Because PHMSA was still drafting regulations associated with the passage of the FAST Act, the NTSB classified Safety Recommendations R-15-14 and R-15-15 Open—Acceptable Response. On August 15, 2016, after passage of the FAST Act, PHMSA issued final rule HM-251C, establishing a phase-out schedule for all tank cars in Class 3 flammable liquids service, including tank cars in non-HHFT trains. The NTSB classified Safety Recommendations R-15-14 and R-15-15 Closed—Acceptable Action in our report on the Casselton derailment (NTSB 2017d). We noted in our March 3, 2017, letter to PHMSA that:

The FAST Act kept an implementation schedule for continued use of tank cars in crude oil and ethanol service similar to that provided in [PHMSA final rule HM-251], requiring full DOT-117 compliance by May 1, 2025. However, the FAST Act also requires retrofitting or removing from service tank cars transporting other Class 3 flammable liquids in Packing Group I by May 1, 2025, and in Packing Groups II and III by May 1, 2029.

This phase-out timeline is current as of the date of this report. The FAST Act phase-out mandates do not provide the Secretary of Transportation the discretion to change the compliance dates. In Safety Recommendation R-15-16, the NTSB advocated for a more aggressive phase-out date but recognized that the congressional mandate had overtaken PHMSA's ability to implement the recommended action. Therefore, on February 11, 2020, the NTSB classified Safety Recommendation R-15-16 Closed—No Longer Applicable.

While the eventual phase out of DOT-111 tank cars from flammable liquids service is a positive step, the NTSB is concerned by the current timeline for replacing DOT-111 tank cars with the superior DOT-117 specification. The history of accidents involving DOT-111 tank cars highlights their poor mechanical and thermal survivability, but the FAST Act phase out will leave some DOT-111 tank cars in flammable liquids service until 2029—including the specific combination of DOT-111 tank car and lading that failed and contributed to other hazardous materials releases at East Palestine. Tank car UTLX205907 released flammable liquid (butyl acrylates) through a head-end puncture, a failure mode that the DOT-117 specification, with its required head shield, is specifically designed to prevent. It is likely that if tank car UTLX205907 had met the DOT-117 specification, the consequences of the East Palestine derailment would have been much less severe.

The NTSB has identified other accidents in which the greater vulnerability of the DOT-111 relative to the DOT-117 and other authorized tank car specifications likely contributed to the severity of a hazardous materials release. From 2013 through 2023, the NTSB investigated 17 accidents in which damaged DOT-111 and CPC-1232 tank cars released hazardous materials. (See table 17.) In 15 of these accidents (88%), the hazardous materials release likely would have been prevented or reduced by the use of a more robust tank car specification, such as the DOT-117, with a thicker tank shell, thermal protection, and consistent use of full-height head shields.

Table 17. Hazardous materials releases from DOT-111 tank cars.

NTSB Accident Number	Location and Date	Breached Hazardous Materials DOT-111s	Description	Specification Likely Contributed to Release
HMD23LR002	Reed Point, Montana, 6/24/2023	9	Nine DOT-111s were mechanically breached, releasing molten sulfur and asphalt into the Yellowstone River.	Yes
RRD23MR005	East Palestine, Ohio, 2/3/2023	8	Eight DOT-111s were breached, three carrying hazardous materials. A pool fire damaged 5 other tank cars carrying vinyl chloride.	Yes
RRD20LR005	Tempe, Arizona, 7/29/2020	1	One DOT-111 carrying cyclohexanone released 2,200 gallons from its damaged manway cover after falling from a bridge.	No
RRD20FR002	Draffin, Kentucky, 2/13/2020	2	Two DOT-111s at the head of the train were breached by head punctures and shell cracks, releasing 38,400 gallons of burning ethanol. DOT-117Rs positioned on either side were not breached.	Yes
RRD19FR008	Sarnia, Ontario, 6/28/2019	1	One DOT-111 derailed in the Sarnia tunnel and released 13,000 gallons of sulfuric acid from a head puncture.	Yes
RRD19FR007	Forth Worth, Texas, 4/24/2019	1	One DOT-111 released 28,800 gallons of burning ethanol when its head and shell sustained large mechanical tears. Two DOT-117Rs were also punctured, releasing an additional 38,000 gallons.	Yes

NTSB Accident Number	Location and Date	Breached Hazardous Materials DOT-111s	Description	Specification Likely Contributed to Release
DCA17FR011	Hyndman, Pennsylvania, 8/2/2017	2	One DOT-111 was mechanically breached and released molten sulfur through a shell tear; a second released asphalt from a BOV.	Yes
DCA17SH002	Money, Mississippi, 4/30/2017	1	One CPC-1232 tank car was pushed into a DOT-117J tank car resulting in a breached head that released 30,000 gallons of crude oil.	Yes
DCA17MR007	Graettinger, Iowa, 3/10/2017	14	Fourteen DOT-111s sustained head and shell breaches and one thermal tear, releasing 322,000 gallons of ethanol.	Yes
DCA17SH001	Fredericksburg, Virginia, 11/2/2016	1	One DOT-111 fractured at a weld during a hard coupling event and released 68 gallons of ethanol.	No
DCA15FR016	Lesterville, South Dakota, 9/19/2015	3	Two DOT-111s sustained head and shell breaches from coupler impacts, and one CPC-1232 BOV opened. The three tanks cars released 49,700 gallons of ethanol that ignited.	Yes
DCA15FR009	Heimdal, North Dakota, 5/6/2015	6	Six CPC-1232s were breached by two head punctures, two thermal tears, and one open BOV, releasing 96,000 gallons of crude oil.	Yes
DCA15FR005	Mount Carbon, West Virginia, 2/16/2015	20	Two CPC-1232s sustained mechanical shell breaches and three had BOV releases. This led to 13 other CPC-1232s sustaining thermal tears, releasing 378,000 gallons of crude oil.	Yes
DCA14FR008	Lynchburg, Virginia, 4/30/2014	3	One CPC-1232 was breached by a mechanical shell tear, and two CPC-1232s released lading through BOVs.	Yes
DCA14FR002	Plaster Rock, New Brunswick, 1/8/2014	3	Two DOT-111s sustained mechanical head and shell breaches, and one CPC-1232 had a BOV release. Together, they released 60,000 gallons of burning crude oil. Pool fires resulted in damage to three butane tank cars that were subjected to a vent and burn.	Yes

NTSB Accident Number	Location and Date	Breached Hazardous Materials DOT-111s	Description	Specification Likely Contributed to Release
DCA13SR006	Casselton, North Dakota, 12/30/2013	18	Eighteen DOT-111s released crude oil from head and shell punctures; three other DOT-111s released crude oil from thermal tears. The total release was 476,000 gallons.	Yes
DCA13SR006	Lac-Mégantic, Quebec, 7/6/2013	60	Sixty DOT-111 tank cars released crude oil from head and shell punctures, resulting in 47 deaths.	Yes

2.4.2.3 Acceleration of DOT-111 Tank Car Phase Out

The DOT-111 specification's known poor derailment performance warrants removing the specification from hazardous materials service as quickly as possible. Although its ability to accelerate the phase out of DOT-111 tank cars is curtailed by the FAST Act, PHMSA has acknowledged the safety benefits of an expedited replacement or retrofit schedule. In response to the East Palestine derailment, PHMSA urged companies that own and use DOT-111 tank cars in flammable liquids service to consider replacing them with DOT-117 or DOT-117R specification tank cars as soon as practicable in the interest of public safety (PHMSA 2023b). As stated in its March 22, 2023, safety advisory, PHMSA believes it is possible for tank car owners and the shipping industry to acquire enough DOT-117 tank cars for flammable liquids service well before the May 1, 2029, phase-out date mandated by the FAST Act (PHMSA 2023b). PHMSA also expressed confidence that this can be accomplished with existing shop capacity. Similarly, the FRA's January 2024 report on its Legacy Tank Car Focused Inspection Program noted that the Railway Supply Institute has previously indicated that it may be technically and operationally feasible to accelerate the May 2029 DOT-111 phase-out deadline by 1 year (FRA 2024).

However, the DOT-111 specification continues in widespread flammable liquids service. According to the AAR, there were almost 26,600 DOT-117 tank cars and about 6,700 pressure tank cars (DOT-105 and DOT-112 specifications, which exceed the DOT-117 requirements) used to transport flammable liquids other than crude oil and ethanol in 2023, while about 25,300 DOT-111 and CPC-1232 tank cars are still in use for other flammable liquids (AAR 2024b). In other words, about 43% of tank cars transporting flammable liquids other than crude oil and ethanol still did not meet the DOT-117 specification in 2023. Further, the 2024 FRA report found that while some tank car owners are on track to meet the May 2029 phase-out deadline, economic factors create disincentives for a faster phase out (FRA 2024). The NTSB

concludes that voluntary industry action to improve the safety of the tank car fleet by completing the phase out of remaining DOT-111 tank cars in flammable liquids service ahead of the FAST Act mandate is feasible, but such action is unlikely because of economic and business disincentives. As of the date of this report, congressional action has been proposed to accelerate the phase out of certain tank cars, including the DOT-111 specification, from flammable liquids service by May 1, 2025, 4 years sooner than required under the FAST Act.¹⁴⁴ The NTSB recommends that PHMSA obtain the necessary legislative authority and accelerate the deadline for removing specification DOT-111 tank cars from flammable liquids service.

2.4.2.4 Non-pressure Tank Cars in Other Hazardous Materials Service

The NTSB is concerned by continued use of DOT-111 and similar tank cars in hazardous materials service partially because hazardous materials releases can cascade: the failure of one tank car can fuel a fire, which can lead other tank cars to release lading. In East Palestine, DOT-111 tank cars carrying flammable and combustible liquids likely contributed to fires that caused hazardous materials releases from PRDs fitted to pressure tank cars—pressure tank cars that remained intact during the derailment and otherwise would have retained lading. The East Palestine derailment demonstrates that hazardous materials tank cars with relatively poor derailment survivability can adversely affect the lading retention of more resilient tank cars, such as DOT-105 tank cars. The NTSB concludes that the presence of DOT-111 tank cars carrying hazardous materials in a mixed freight train increases the risk of lading releases from other, more resilient tank cars during a derailment.

The FAST Act does not require non-pressure tanks used to transport combustible or other non-flammable hazardous materials to meet the DOT-117 specification. This means there is no phase-out schedule for DOT-111, AAR-211, or CPC-1232 tank cars in other than flammable liquids service (such as combustible or other non-flammable hazardous materials). Of the three DOT-111 tank cars that released hazardous materials during the East Palestine derailment, two were transporting combustible liquids and therefore were not subject to the FAST Act. Therefore, the NTSB recommends that PHMSA establish a tank car replacement schedule whereby non-pressure tank cars in any hazardous materials service must meet or exceed the safety standards of the DOT-117 specification; if necessary, obtain legislative authority to act on this recommendation.

¹⁴⁴ See S. 576, the proposed Rail Safety Act of 2023. The text of the bill as introduced on March 3, 2023, is available here:

<https://www.govinfo.gov/content/pkg/BILLS-118s576is/pdf/BILLS-118s576is.pdf>.

2.4.3 Pressure Tank Cars

The five DOT-105s that released material (the VCM tank cars) did so through a combination of PRD actuation and the vent and burn procedure initiated by the incident command in response to NS's and its contractors' statements about polymerization causing a BLEVE. The NTSB therefore focused our investigation on the VCM tank car tanks and fittings to determine whether their design or construction contributed to the hazardous materials releases caused by postderailment fires.

2.4.3.1 Tank Car and Fittings Certification

Under 49 *CFR* 179.5, a tank car must have a certificate of construction before entering service. Under 49 *CFR* 179.3, applications for approval of designs, materials of construction, conversion, or alteration of tank car tanks, complete with detailed prints, must be considered and approved by the AAR Tank Car Committee or other appropriate committees before a certificate of construction can be issued. Applicants must specify commodities and certify that the tank car and its service equipment (such as PRDs) are compatible with the specified lading as described in the AAR MSRP, M-1002, Specifications for Tank Cars. The AAR also approves PRD designs through a separate process, which asks the applicant to specify the commodity with which the PRD will be used. Applicants must test a PRD's flow rate using a test fluid such as steam, air, or natural gas. The AAR approval processes for tank cars and PRDs do not include independent evaluation of whether an applicant's certification of compatibility is accurate.

Four of the five derailed VCM tank cars were certified for "vinyl chloride." The fifth, GATX95098, was certified for "propylene oxide and products authorized in DOT 173 [sic] for which there are no special commodity requirements and nonregulated commodities compatible with this class of car." VCM is a Division 2.1 flammable gas and is therefore subject to the special requirements of 49 *CFR* 173.314(j). However, the NTSB did not identify evidence that the tank car did not meet these requirements or that its original lading certification materially affected its suitability for use in VCM service or created a specific safety risk.

The certificates of construction for three of the VCM tank cars reference design drawings that specify aluminum components: for TILX402025, the version of a PRD with an aluminum-coated spring, and for OCPX80235 and OCPX80179, an aluminum protective housing cover. The NTSB's postderailment examinations of the VCM tank cars also identified aluminum valve handwheels on tank car OCPX80370.

The Oxy Vinyls SDS for VCM lists aluminum as incompatible with VCM because it may result in violently exothermic (heat-producing) reactions. While expert testimony at the NTSB Investigative Hearing called into question the scientific basis for this incompatibility warning, the NTSB is concerned that tank cars certified for VCM service had protective housing covers, valve handwheels, and PRD components made of a material specifically described as incompatible by the lading's SDS.¹⁴⁵ There is no evidence that the AAR Tank Car Committee or any third-party approver took note of this incompatibility or raised concerns, and the five derailed tank cars transporting VCM were in service with aluminum components.

The current approval process for certificates of construction depends on the accuracy of manufacturers' own representations of their products' compatibility with loadings and compliance with regulations. The AAR does not appear to consistently verify these representations through independent testing, reference to relevant scientific literature, or demonstration. The AAR's approval process was insufficient to prevent the VCM tank cars involved in the East Palestine derailment from being certified despite the possible incompatibility of fittings with the specified lading. The NTSB concludes that the current AAR tank car certificate of construction approval process lacks a means of verifying manufacturers' claims and is therefore insufficient to ensure that tank cars and their fittings are appropriate for their specified lading. The AAR's current review process cannot reliably identify tank cars whose fittings may be incompatible with the specified lading, creating safety hazards that could be avoided by more careful review, appropriate testing, or use of SDSs and other sources of hazard information. The NTSB recommends that the AAR revise the MSRP, M-1002, Specifications for Tank Cars, to establish criteria and procedures for manufacturers of tank car service equipment to demonstrate compatibility of PRDs and other AAR-approved service equipment with intended loadings. The NTSB also recommends that the FRA monitor the progress of the AAR's action on R-24-20 and use its regulatory authority to ensure that the AAR addresses weaknesses in its tank car service equipment approval process.

2.4.3.2 Observed PRD Performance

Before the vent and burn, the DOT-105 tank cars that lost lading (the VCM tank cars) did so through PRD actuation. These releases began after four of the VCM tank cars were exposed to fire conditions and generally ended by mid-day on February 4, 2023, as many of the fires were extinguished. The last PRD actuation on a VCM tank car occurred about 5:30 p.m., when tank car OCPX80179 vented

¹⁴⁵ NTSB Investigative Hearing Transcript, Day 1, pp. 183-84.

energetically for about 70 minutes. This PRD release was significantly more violent and protracted than any other release observed following the derailment, suggesting that the PRD was venting VCM at a higher pressure than normal. After the 70-minute discharge, the PRD ceased operation and did not actuate again.

The NTSB's initial on-site examinations of the VCM tank cars found that the tank car protective housings that had been fitted with aluminum protective covers were missing those covers (OCPX80235, OCPX80179, and GATX95098), while steel protective covers had remained attached and largely intact (OCPX80370 and TILX402025). This is likely because aluminum has a lower melting point than steel: 1,221°F compared to 2,500-2,800°F, depending on the type of steel. Protective housings that originally had aluminum covers contained metallic debris that NTSB Materials Laboratory testing confirmed was mostly aluminum, indicating that the covers had melted and entered the housing itself. As a result, three PRD top guides contained aluminum debris that had melted and resolidified.

The manufacturer of these PRDs warns in its product manual against allowing foreign matter into the top guide because foreign matter could hinder the flow of discharging fluid (Midland Manufacturing 2021). It is unclear whether the presence of aluminum in the PRD top guides of tank cars OCPX80235, OCPX80179, and GATX95098 adversely affected the function of their PRDs. Although the top fittings for tank car OCPX80370 included aluminum valve hand wheels, its housing cover was made of carbon steel, and there were no signs of aluminum debris in the PRD's top guide. It is therefore unlikely that melted aluminum damaged or obstructed the PRD on tank car OCPX80370.

The NTSB recovered all five PRDs for bench testing, disassembly, and examination at the Trinity Rail Maintenance Services Saginaw Plant in Saginaw, Texas, on March 15-16, 2023. One PRD (from tank car GATX95098) was fused to the pressure plate, and the top guide discharge structure and top guide bushing were missing. The PRD was too damaged to be tested. None of the other four PRDs performed to specification in their as-received condition when bench tested; this is not unusual for PRDs recovered from tank cars that have been exposed to fire conditions. Three PRDs (TILX402025, OCPX80235, and OCPX80179) began to leak or discharge significantly below their specified start-to-discharge pressure.¹⁴⁶ The PRD valve stem from OCPX80370 was stuck closed and did not leak or discharge when pressurized to 275 psig, or more than 25 pounds per square inch above its

¹⁴⁶ Tank car TILX402025 was not exposed to fire before the vent and burn, and there is no evidence that its PRD actuated to reduce tank pressure. Its PRD was likely damaged during the vent and burn.

designed start-to-discharge pressure; for safety reasons, no higher pressures were attempted.

When investigators disassembled and examined the PRDs, they found damage to internal components, including parts that had become stuck together, deteriorated aluminum coatings on interior parts, signs of corrosion, and bent or permanently compressed springs. The nature of the damage suggests that exposure to heat and corrosive gases—such as the hydrogen chloride produced by the burning VCM—during lading releases is sufficient to explain the PRDs' degraded condition at the time of bench testing. However, to preserve chemical and physical evidence, the PRDs were not cleaned before being shipped for testing and examination. Corrosion that began during lading releases may have continued during the 6 weeks between the derailment and bench testing. Therefore, the bench tests and examinations may not accurately indicate the level of corrosion present in the PRDs on February 3-4, 2023.

The postderailment examinations found no evidence of any foreign matter, such as PVC, obstructing the function of the PRDs or valves. This indicates that the observed increase in start-to-discharge pressure (for the PRD from tank car OCPX80370) was a result of mechanical or chemical damage to PRD components, not of polymerization producing solid material able to obstruct a PRD. While the evidence does not support a definitive determination about how the presence of aluminum affected PRD performance, the NTSB's examinations confirmed that aluminum components, including protective housing covers and PRD spring coatings, did not remain intact and likely melted when exposed to burning VCM during actuation. The NTSB concludes that while the use of aluminum in the VCM tank cars and PRDs rendered them susceptible to thermal damage, there is insufficient evidence to determine whether this greater susceptibility created a safety hazard or contributed to the release of hazardous materials following the East Palestine derailment.

2.4.4 High-Hazard Flammable Trains

Following our participation in the TSB's investigation of the Lac-Mégantic, Quebec, derailment and fire involving a crude oil unit train, the NTSB issued the following safety recommendations to the FRA:

Work with the Pipeline and Hazardous Materials Safety Administration to expand hazardous materials route planning and selection requirements for railroads under Title 49 *Code of Federal Regulations* 172.820 to include key trains transporting flammable liquids as defined by the

Association of American Railroads Circular No. OT-55-N and, where technically feasible, require rerouting to avoid transportation of such hazardous materials through populated and other sensitive areas. (R-14-1)¹⁴⁷

We issued a corresponding recommendation to PHMSA:

Work with the Federal Railroad Administration to expand hazardous materials route planning and selection requirements for railroads under Title 49 *Code of Federal Regulations* 172.820 to include key trains transporting flammable liquids as defined by the Association of American Railroads Circular No. OT-55-N and, where technically feasible, require rerouting to avoid transportation of such hazardous materials through populated and other sensitive areas. (R-14-4)¹⁴⁸

In response, PHMSA issued an NPRM on August 1, 2014, titled “Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains” (79 Fed. Reg. 45016).¹⁴⁹ In our comments on the NPRM, we noted several concerns with the proposed rule. One touched on a possible misapplication of Safety Recommendation R-14-4:

Safety Recommendation R-14-4 urges PHMSA to include “key trains” carrying flammable liquids in its route-planning requirement. The recommendation refers to the definition of key train in AAR Circular No. OT-55-N, which lists 20 tank cars of any combination of hazardous material as the threshold number of tank cars in the consist. In referring to the AAR circular, we intended to suggest using a preexisting industry standard for route planning, but not to endorse a 20-tank-car threshold for HHFTs. We caution you not to use Safety Recommendation R-14-4 to imply that we endorse a 20-tank-car threshold for any other purpose.

We also noted the narrow range of hazardous materials encompassed by the HHFT definition, which included only Class 3 flammable liquids:

¹⁴⁷ Safety Recommendation R-14-1 is currently classified Closed–Acceptable Action.

¹⁴⁸ Safety Recommendation R-14-4 is currently classified Closed–Acceptable Action.

¹⁴⁹ See section 1.11.2 for more information about this rule and its relationship to later versions of the HHFT definition.

We believe the definition should include a broad range of hazardous materials, similar to the revised definition of a key train in AAR Circular No. OT-55-N. The circular's reference to "any combination of hazardous material" includes hazard class 2, division 2.1 (flammable gas) materials and combustible liquids, as defined at 49 *CFR* 173.115(a) and 173.120(b).

On May 8, 2015, PHMSA published the final rule, HM-251, defining an HHFT as a train with 20 or more tank cars transporting a Class 3 flammable liquid in a single block or 35 or more such tank cars throughout the consist (80 Fed. Reg. 26644). As a result, the NTSB classified Safety Recommendations R-14-1 and R-14-4 Closed–Acceptable Action on September 16, 2015. The FAST Act, signed into law December 4, 2015, includes a statutory definition of HHFT that uses the same tank car counts and commodities; under the FAST Act, PHMSA no longer has the discretion to change the definition of HHFT (PL 114-94).

The rules governing the operation of HHFTs are designed to prevent or mitigate a derailment involving a large number of flammable liquids tank cars, partially to reduce the risk of one breached tank car compromising others. When exposed to fire conditions, flammable liquids tank cars can experience a cascade of releases as each breached tank car spreads the fire to involve more tank cars. The risk and potential scope of this cascading failure mode increases with greater numbers of flammable liquids tank cars.

Train 32N was not an HHFT, but the NTSB's investigation determined that the sequence of hazardous materials releases was similar to what the HHFT rules are designed to prevent. The East Palestine derailment led to mechanical breaches in DOT-111 tank cars that released flammable and combustible liquids, caused fires that exposed more tank cars to heat, and eventually released a Class 2.1 flammable gas through PRD actuation from DOT-105 tank cars that were mechanically intact. The sequence of hazardous materials releases observed at East Palestine shows that non-HHFT mixed freight trains are vulnerable to cascading hazardous materials releases if the consist includes hazardous materials and tank cars relatively likely to compromise the lading retention of other tanks cars in the consist. The breached DOT-111 tank cars caused other tank cars to release lading even though train 32N had fewer than 20 (or 35) hazardous materials tank cars and even though most of the hazardous materials in the derailed tank cars were not Class 3 flammable liquids.

While it is unclear whether applying the operating requirements for HHFTs to train 32N would have mitigated the postderailment fires, the postderailment releases show that the release scenario addressed by HHFT regulations is not confined to

HHFT trains: the specifics of tank car derailment performance and presence of non-flammable liquids hazardous materials are both relevant to assessing a mixed freight train's level of hazard. Therefore, the NTSB concludes that cascading hazardous materials releases are not unique to HHFTs, and the probability of a cascading hazardous materials release depends in part on variations in tank car survivability and on the presence of hazardous materials other than Class 3 flammable liquids, such as combustible liquids and Division 2.1 flammable gases. Accordingly, the NTSB recommends that PHMSA revise the definition of HHFT to account for differences in survivability between tank car specifications and to include hazardous materials other than flammable liquids, such as combustible liquids and Division 2.1 flammable gases, that can contribute to cascading hazardous materials releases; if necessary, obtain legislative authority to act on this recommendation.

2.4.5 Key Trains

The definition of key train in AAR Circular OT-55 includes a threshold of 20 car loads of hazardous materials, or a single car load of especially hazardous materials such as spent nuclear fuel, and a train that meets either threshold is subject to recommended practices for maximum speeds and additional procedures for defective bearings. In setting these two thresholds, the definition reflects different levels of lading hazards. However, it does not distinguish between tank cars with different probabilities of releasing hazardous materials during an accident. As discussed above in section 2.4.2.2, the DOT-111 specification, and by extension the similar AAR-211 specification, are generally less survivable than tank cars that meet the DOT-117 standard. A simple tank car count therefore does not provide an accurate representation of how hazardous a train is; the specifications of the tank cars transporting hazardous materials are also relevant to the assessment. The NTSB concludes that the definition of key train in AAR Circular OT-55 does not account for differences in survivability between different tank car specifications, and the DOT-111 and AAR-211 specifications can pose an elevated risk of a hazardous materials release compared to other specifications, such as the DOT-117. The NTSB recommends that the AAR revise the definition of key train in Circular OT-55 to designate as a key train any train containing tank cars transporting hazardous materials that do not meet the DOT-117 standard.

2.5 The Vent and Burn

An NS contractor performed a vent and burn of all five derailed VCM tank cars on February 6, 2023. One tank car, TILX402025, had not released VCM through its PRD and was therefore likely full at the time of the vent and burn. The other four tank

cars had released unknown amounts of lading through PRDs before the vent and burn; the vent and burn released whatever lading was still contained in the tank cars.

The incident commander approved this action in the belief that exposure to heat during postderailment fires had caused the VCM to begin polymerizing and that the vent and burn was necessary to prevent a polymerization reaction within at least one tank car from causing a catastrophic tank rupture. This belief was based on statements from NS and its contractors, which formed their judgment based on a reading of VCM hazard information, observed PRD activity, and infrared thermometer temperature measurements taken from the shells of VCM tank cars. NS consistently advocated for a vent and burn to prevent a tank failure, though it considered and rejected alternative means of unloading VCM from the derailed tank cars.

Oxy Vinyls, which was providing support to NS and its contractors but was not in direct communication with the incident commander, concluded based on the same evidence and its own knowledge of VCM that dangerous polymerization was not occurring. Oxy Vinyls shared its conclusions with NS and NS's contractors while on the scene; these conclusions were not communicated to the incident commander.

The NTSB's investigation into the vent and burn addressed four core subjects: whether dangerous polymerization was occurring within the derailed and fire-exposed VCM tank cars, the quality of the VCM hazard information available to responders, the communication and decision-making processes that led to the vent and burn, and the availability of sound criteria for when a vent and burn is appropriate.

2.5.1 Polymerization

The NTSB obtained expert opinions on VCM polymerization from Oxy Vinyls' LaPorte plant technical manager and a chemistry professor at Indiana University. Based on their interviews, hearing testimony, and references to scientific literature, stabilized VCM—in the case of East Palestine, VCM packaged in tank cars in a low-oxygen environment—cannot polymerize when exposed to heat without the presence of an initiator (free radicals), and it cannot sustain a polymerization reaction without the continued introduction of free radicals, which are consumed during the polymerization process. In other words, a runaway polymerization reaction is not possible if the VCM is stabilized, and VCM will remain stabilized as long as it remains in a low-oxygen environment.

Previous NTSB investigations and PHMSA incident reports further support that stabilized VCM (that is, VCM in a low-oxygen environment) is unlikely to polymerize in

a tank car. The NTSB has investigated seven rail accidents in which VCM tank cars released lading. These investigations are summarized in table 18.

Table 18. NTSB investigations of VCM releases.

NTSB Report Number	Location	Date	Notes	Evidence of VCM Polymerization
NTSB/RAR-70-2	Glendora, Mississippi	9/11/1969	Two tank cars released VCM, resulting in fires and several explosions.	No
NTSB/RAR-72-6	Houston, Texas	10/19/1971	Two VCM tank cars were punctured and released VCM, which exploded; the explosion was a result of rapid combustion.	No
NTSB/RAR-78-8	Lewisville, Arkansas	3/29/1978	A punctured tank car released VCM, which immediately exploded.	No
NTSB/RAR-81-1	Muldraugh, Kentucky	7/26/1980	Two VCM tank cars were punctured in a derailment and released lading that then exploded. Another VCM tank was exposed to fire, vented lading through its PRD, and likely reached temperatures of 185-190°F.* A VCM tank car was vented and burned 4 days after the derailment, along with other fire-exposed tank cars.	No
NTSB/RAR-83/05	Livingston, Louisiana	9/28/1982	Two VCM tank cars were breached during a derailment and contributed to a fire. Three more VCM tank cars began to vent lading as a result of fire exposure. One VCM tank car was thermally breached and exploded, along with a tank car containing tetra-ethyl lead. Six VCM tank cars were vented and burned about 2 weeks after the derailment to dispose of their lading.	No
NTSB/RAR-05/01	Tamaroa, Illinois	2/9/2003	A punctured VCM tank car released part of its load. The rest was removed using a hot tap.	No
NTSB/RAR-14/01	Paulsboro, New Jersey	11/30/2012	One punctured VCM tank car released a cloud of vapor.	No

* This temperature estimate is based on the temperature / vapor pressure curve for VCM.

No NTSB investigation of a VCM release from a tank car has identified evidence of polymerization. In the seven investigations summarized in table 18, four VCM releases (Glendora, Houston, Lewisville, and Muldraugh) resulted in explosions

attributable to combustion. In the Livingston release, one tank car exploded as a result of thermal failure during exposure to an intense fire (a non-VCM tank car also exploded). In these five cases, released VCM ignited—sometimes explosively—but did not show signs of polymerization. In the Paulsboro release, the VCM spread as a vapor cloud and was exposed to atmospheric oxygen for an extended period but showed no signs of polymerization.¹⁵⁰ These releases suggest that VCM does not tend to polymerize in a tank car exposed to heat or even one breached by outside mechanical forces.

PHMSA maintains the Hazmat Incident Database, which contains information reported on Hazardous Materials Incident Report Form 5800.1. A database query for 1971 through 2023 identified 73 incidents involving UN1086 (stabilized VCM) in transportation.¹⁵¹ Five reports from NS listed “polymerization” as the cause of package failure—the reports NS filed for the five VCM tank cars involved in East Palestine. These tank cars released lading through PRD activity and were breached with explosives during the vent and burn, not by polymerization. There were no other reports of polymerization in the event descriptions or cause of failure descriptions for the remaining 68 incidents.

The NTSB’s analyses of on-scene observations cited by NS as signs of polymerization assess not only whether the observations were consistent with polymerization, but also whether a more probable explanation is sufficient to account for the observation. The two credible observations are PRD activity and tank temperature measurements, both discussed below.

The PRDs on the four VCM tank cars exposed to fire cycled for several hours before they stopped actuating. Based on the cessation of PRD activity and traces of a volatile organic compound (plausibly VCM) detected near the protective housing of OCPX80370 on February 5, 2023, the SPSI president believed that the PRD had become plugged with polymer (PVC), causing it to release small amounts of vapor but not enough to combust. The presence of PVC within the PRD would have indicated that polymerization was occurring within the tank. However, the post-vent and burn examination of disassembled PRDs found no signs of foreign matter, such as PVC, obstructing their operation. As discussed in section 2.4.3.2, physical damage

¹⁵⁰ The NTSB’s report for the Tamaroa release does not directly state that the released VCM did not ignite, but it does note that the punctured tank car was “not involved in the fire” that affected other derailed equipment (NTSB 2005).

¹⁵¹ The PHMSA database contains individual reports for each tank car when incidents involve multiple tank cars of VCM in a derailment.

to the PRD from tank car OCPX80370 was adequate to explain an elevated start-to-discharge pressure. This PRD's valve stem was stuck closed, and the PRD would not actuate even at pressures above its specified start-to-discharge pressure. The condition of the PRD suggests that it was no longer functioning normally after being exposed to fire conditions and burning VCM during actuation, but that its observed behavior was unrelated to polymerization. The NTSB concludes that postaccident examinations, which found no solidified chemical matter blocking pressure relief devices and other tank car service equipment openings, do not indicate that a polymerization reaction occurred within any of the five VCM tank cars.

During postaccident testing, the other three testable PRDs (from tank cars TILX402025, OCPX80235, and OCPX80179) all began to leak or discharge below their specified start-to-discharge pressures because of physical damage. Two of these PRDs (OCPX80235 and OCPX80179) cycled during fire exposure and eventually ceased operation. Because PRD actuation is a function of pressure and pressure is a function of temperature, the NTSB was able to use the postaccident test pressures to determine a set of maximum temperatures for the lading in those two VCM tank cars in the hours before the vent and burn. (For OCPX80235, the highest temperature the lading could reach without actuating a PRD was about 136°F; for OCPX80179, about 150°F. See below for methodology.) Further, SPSI and SRS recorded temperature measurements for all five VCM tank cars while monitoring for a temperature increase that could indicate polymerization. If those measured temperatures remained below the deteriorated PRDs' start-to-discharge pressures, then the temperature of the lading alone would explain the cessation of PRD activity.

A PRD on a tank car transporting a liquefied compressed gas reaches its start-to-discharge pressure when the temperature of the lading increases, raising the lading's vapor pressure (which normally equals the internal tank pressure).¹⁵² *Yaws' Critical Property Data for Chemical Engineers and Chemists* provides vapor pressure values for VCM at different temperatures (Yaws 2014). Based on those values, VCM vapor pressure rises with temperature along the curve shown in figure 30.¹⁵³

¹⁵² The phase change from a liquid to a gas typically creates a much greater pressure change than the thermal expansion of a liquid.

¹⁵³ Subsequent exact values for temperatures and vapor pressures in this report are taken directly from table 12 of *Yaws' Critical Property Data for Chemical Engineers and Chemists*.

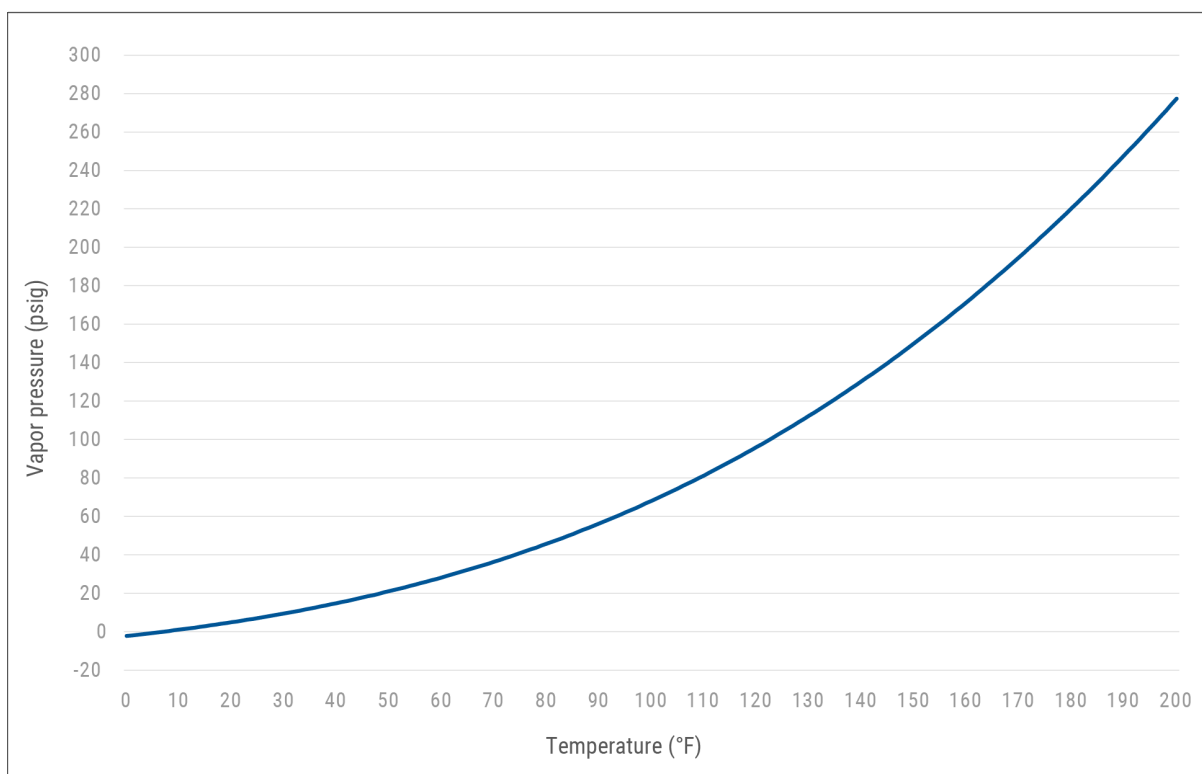


Figure 30. Graph of VCM vapor pressure by temperature.

The lowest start-to-discharge pressure identified during postaccident testing of a PRD known to actuate during fire exposure and then cease was 122 psig (OCPX80235). This pressure corresponds to a lading temperature of about 136°F. For OCPX80179, the start-to-discharge pressure identified during testing was 149.7 psig, which corresponds to a temperature of about 150°F. Typical measured temperatures for tank cars OCPX80235 and OCPX80179 ranged from 62 to 67°F. Similar analysis applies to the PRD with an elevated start-to-discharge pressure (from tank car OCPX80370). Given that this PRD would not start to discharge at 275 psig during testing, the lading temperature would have to exceed 199°F to actuate the PRD. The highest measured temperature for this tank car was 139°F, indicating a pressure of about 128 psig—much too low to overcome the stuck valve stem. Therefore, lading temperatures (and therefore internal tank pressures) are sufficient to explain the cessation of PRD activity even for PRDs with reduced start-to-discharge pressures, and PRD activity is not indicative of polymerization.

NS and its contractors also interpreted tank car temperatures as signs of polymerization. At Oxy Vinyls' recommendation, SPSI and SRS collected regular tank car temperature measurements on February 5-6, 2023, using an infrared thermometer to monitor the exterior shell surfaces at points where the jacket and thermal protection blanket had been torn away in the derailment. The measured

temperatures are listed in table 3. In discussions with the incident commander and the NTSB on scene, NS noted a 3°F increase in temperature for tank car OCPX80370 as an indication that polymerization was occurring. This increase to 138°F on the afternoon of February 5 was close to the highest temperature recorded on a tank car shell (139°F, measured during a brief fire under the tank car about midnight on February 5-6). Tank car OCPX80370 was the only tank car to show significant variations in temperature during monitoring.¹⁵⁴ The temperature for OCPX80370 is plotted in figure 31 (blue), along with a trendline (red).

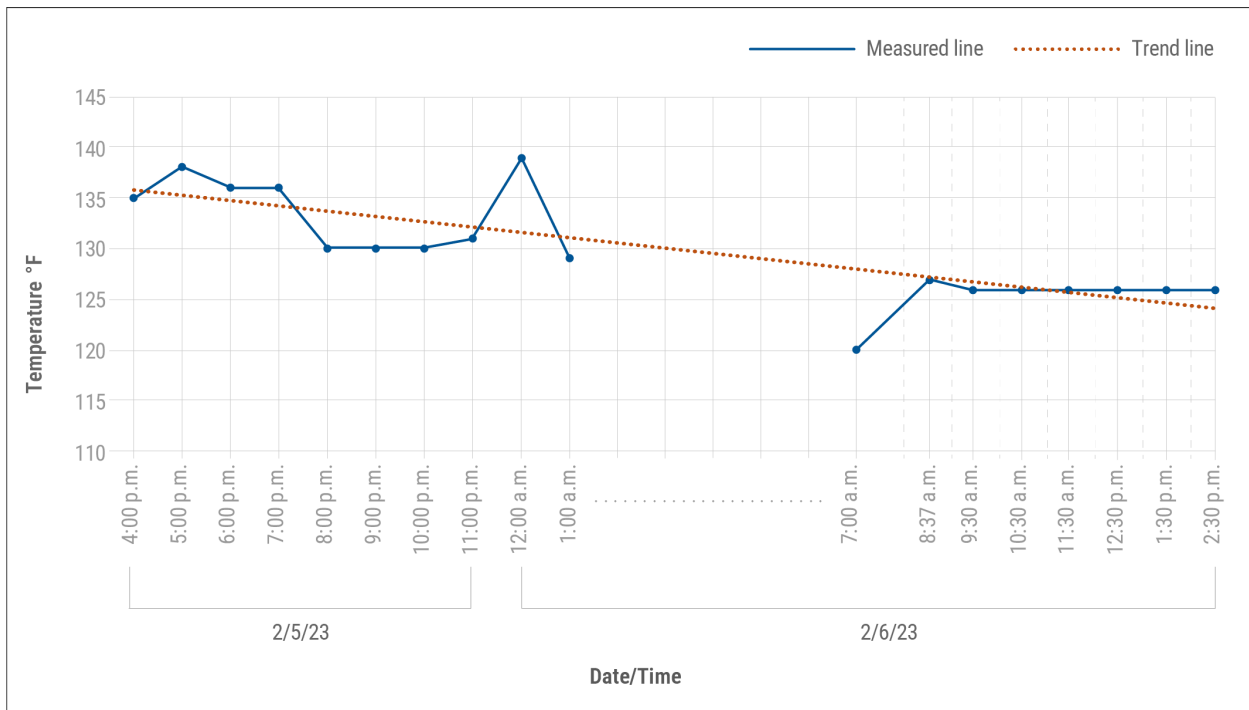


Figure 31. Measured temperatures and trendline for OCPX80370.

According to information Oxy Vinyls provided the NTSB after the vent and burn, a runaway polymerization reaction would produce “a rapid, significant, and sustained increase in temperature and pressure.” The dashed red trendline in the figure shows a gradual decline instead. The surface temperature measurements therefore do not indicate exothermic polymerization in tank car OCPX80370. Measured variations in temperature were likely the result of environmental conditions and the limitations of the method used. Because of non-uniform heating caused by

¹⁵⁴ Two other tank cars—OCPX80179 and GATX95098—each have a single outlier temperature measured at 7:00 a.m. on February 6. Measurements taken about 1.5 hours later showed both cars back at their more typical temperatures of about 65°F. Because these outliers are the only elevated temperatures for these tank cars and they were taken at the same time, they are likely skewed by some unknown error or variable in the environment or measuring technique.

internal circulation and exposure of parts of the tank car shells to external fire, the ideal location to collect temperature measurements would have been from the tank car's thermometer well. But access to top fittings houses was hampered by fires and thermally damaged fittings, and infrared thermometer measurements were the only ones available for tank car OCPX80370. The SPSI president testified that he did not have confidence in the temperature readings because pieces of jacket or thermal protection blanket might have been interfering with attempts to take the temperature of the bare tank shell, meaning that not every measurement was taken from the intended part of the tank.¹⁵⁵

Tank car OCPX80370's generally elevated temperature relative to the other tank cars was likely a result of the tank car leaning against a burning hopper car for 2-3 days. The nearby fire may have slowed the cooling of the lading and compromised the accuracy of the temperature measurements; infrared thermometers cannot distinguish between radiated heat (the internal warmth of the tank car) and reflected heat (energy released by the hopper car fire and bounced off the tank car shell). Measured fluctuations in temperature were therefore likely the result of environmental conditions, heat being reflected from the tank car, and the limitations of the measurement method. Even discounting the effects of nearby external heat sources, temperature measurements of tank car OCPX80370 were consistent with cooling lading, not runaway polymerization. The NTSB concludes that the observed downward temperature trend in tank car OCPX80370 indicates that polymerization was not occurring within the tank car, contrary to the representation by NS and its contractors.

In fact, all four VCM tank cars that released material through PRDs must have reached temperatures significantly higher than 139°F during the postderailment fires and then cooled before SPSI and SRS began taking measurements. These tank cars were equipped with PRDs with start-to-discharge pressures of 247.5 psig. During the first releases, before burning VCM could have begun to impact PRD performance, the vapor pressure of the VCM within the four venting tank cars must therefore have reached a minimum of 247.5 psig, and the lading a corresponding minimum temperature of about 189°F. These four tank cars exceeded the highest temperature measured by SPSI without experiencing a runaway polymerization reaction: all four had cooled after the fires were largely extinguished on February 4, as documented in table 3.

¹⁵⁵ NTSB Investigative Hearing Transcript Day 1, pp. 149-50.

Evidence available after the vent and burn also does not support polymerization. During the vent and burn, all five VCM tank cars expelled material, indicating that the cars were still under positive internal pressure. Oxygen and other contaminants therefore could not enter the tank cars before the vent and burn, and the VCM remained in a low-oxygen, stabilized environment not conducive to polymerization. As discussed above, PRDs recovered from all five tank cars did not contain obstructions of PVC, and examinations did not identify foreign matter obstructing their operation. Finally, Oxy Vinyls performed laboratory analyses on residue samples recovered from the interiors of the VCM tank cars. While these analyses did not definitively rule out the presence of PVC (VCM and PVC are chemically similar) they did not find evidence of PVC. The NTSB concludes that the VCM within the derailed DOT-105 tank cars remained in a stabilized environment until the vent and burn and did not undergo polymerization; the vent and burn procedure was not necessary to prevent a polymerization-induced tank rupture. NS's submissions to the PHMSA Incident Database incorrectly describe polymerization as a cause of package failure in all five VCM tank cars. The NTSB recommends that NS update its submissions to the PHMSA Incident Database to accurately reflect the cause of package failures following the East Palestine derailment.

2.5.2 Quality of VCM Hazard Information

Sources of VCM hazard information referenced by NS and its contractors before the vent and burn included the 2020 ERG, Oxy Vinyls' SDS, and The Chlorine Institute's Pamphlet 171. The 2020 ERG and Oxy Vinyls' SDS both list polymerization as a hazard associated with VCM. However, the 2020 ERG and SDS guidance are both intended to address circumstances other than when the VCM is within the interior of a mechanically intact tank car. The SDS guidance is intended to address potential hazards to include industrial settings and other environments distinct from conditions incident to transportation. Given that the SDS is required by regulation to address a wide range of hazards and the 2020 ERG is intended as a quick-reference guide for initial responses to a variety of transportation-related incidents, it is reasonable to expect that both will include guidance that addresses a wide range of applications and requires further context and expertise to use effectively.

Pamphlet 171 includes guidance specifically for emergency response involving intact VCM tank cars. This guidance states that a pressure above 68 psig or a tank surface temperature reading "above ambient temperature" may be indicative of polymerization. While these statements are true—exothermic polymerization produces increases in temperature and pressure—they do not take into consideration other explanations of elevated temperatures and pressures and can lead the reader

to incorrectly conclude polymerization is occurring. Further, Pamphlet 171 may bias the reader against more probable explanations by stating that increased temperature and pressure together mean that polymerization is “most likely occurring in the tank car.” This statement is not true for an intact tank car that has been exposed to a fire or was otherwise externally heated. Further, temperature and pressure are correlated and therefore should not be treated as two separate signs of polymerization.

As discussed in section 2.5.1, expert opinion and historical evidence both indicate that dangerous polymerization of VCM is unlikely within an intact tank car. Pamphlet 171’s claim that increases in temperature and pressure indicate that polymerization is “most likely” occurring in intact VCM tank cars is overstated and therefore misleading. NS and its contractors referred to Pamphlet 171 in addition to the Oxy Vinyls SDS and 2020 ERG while forming their initial judgments that polymerization was occurring within the derailed VCM tank cars. The NTSB concludes that language in The Chlorine Institute’s Pamphlet 171 overstates the probability of VCM polymerization in scenarios where tank cars remain intact, likely leading those using the pamphlet during an emergency response effort to overestimate the likelihood of polymerization. Therefore, the NTSB recommends that The Chlorine Institute review and revise Pamphlet 171 to ensure that its safety messages about VCM polymerization in tank cars are accurate and adequately support determining whether a rail accident poses a risk of polymerization. The NTSB also recommends that Oxy Vinyls update the SDS for VCM to accurately reflect the potential risks of VCM and the hazards that increase such risks.

SPSI and SRS were Level 3 CHLOREP contactors vetted by The Chlorine Institute to provide expertise and a capable emergency response to chlorine incidents. CHLOREP is intended to provide emergency responders—including incident commands—with accurate information and chlorine industry expertise. The capabilities The Chlorine Institute requires for Level 3 contractors do not specifically include vent and burn decision-making, focusing instead on safe field transfer (transloading) of chlorine products from damaged packaging. The Chlorine Institute verifies these capabilities every 3 years.

As the president of SPSI told the NTSB in an interview, one of the reasons SPSI and SRS did not attempt transloading of VCM was concern that the product had already polymerized, making it unsafe to move regardless of the condition of the VCM tank cars’ fittings. However, available evidence did not indicate polymerization, and polymerization had not occurred. SRS and SPSI did not correctly interpret evidence relevant to polymerization, recognize the limitations or inaccuracies of the available written guidance about VCM hazards, or make use of Oxy Vinyls’ expert opinion that available evidence did not point to polymerization. The events at East

Palestine show that knowledge of VCM chemistry sufficient to determine whether polymerization has occurred is relevant to the intended role of Level 3 CHLOREP contractors, which should be capable of transloading VCM whenever it is safe to do so and of providing accurate hazard information to the full incident command. The NTSB concludes that because Level 3 CHLOREP contractors are expected to provide advanced emergency response capabilities, including communicating expertise to other on-scene personnel and the transloading of VCM, these contractors should possess or know how to obtain enough technical knowledge to accurately assess how chemical hazards, such as polymerization, affect a safe response to a VCM incident. The NTSB recommends that The Chlorine Institute review and revise its CHLOREP training and verification programs to ensure that Level 3 contractors possess or can obtain enough technical knowledge of VCM to accurately assess and respond to chemical hazards like polymerization during a VCM incident.

Information recorded on the scene by emergency response contractors, notably the temperatures of the tank cars and the timing of PRD actuation, was relevant to determining whether written guidance was accurate and effective in supporting the emergency response. Fire-exposed VCM tank cars did exhibit elevated temperatures and pressures—which Pamphlet 171 states are indicators of likely polymerization—but later examinations found no evidence that polymerization had occurred. The NTSB concludes that information collected during real-world accidents is a vital resource in ensuring that hazardous materials guidance is suitable for supporting responses to transportation emergencies. The NTSB recommends that NS adopt policies to ensure that its emergency response contractors keep detailed records of information used to make decisions involving hazardous materials, and share this information with shippers, relevant chemical associations, and other entities that provide hazardous materials guidance.

2.5.3 Vent and Burn Communication and Justification

The vent and burn decision began with NS and its contractors interpreting an energetic PRD actuation on the afternoon of February 4, 2023, followed by cessation of PRD activity as a sign that VCM had polymerized and obstructed a PRD, causing a build up of pressure and then preventing the PRD from actuating again. According to the NTSB's interview with the SPSI president, on February 4, SPSI and NS were already “at a vent and burn” decision because of the unusual PRD activity and the polymerization hazard information in the 2020 ERG, Pamphlet 171, and SDS.

Starting on the morning of February 4, NS and its contractors had access to VCM expertise from Oxy Vinyls. Oxy Vinyls called into question the likelihood of

polymerization. In a conference call with SPSI and NS on the afternoon of February 4, Oxy Vinyls personnel in Dallas, Texas, assessed a low probability of polymerization and recommended monitoring the tank cars' temperatures. Runaway exothermic polymerization would produce a rapid, sustained increase in temperature. This rapid, sustained increase in temperature was not occurring, as discussed in section 2.5.1.

On February 5, 2023, representatives from Oxy Vinyls arrived on the scene and met with SPSI and SRS personnel. During this meeting, the Oxy Vinyls logistics process supervisor explained the VCM stabilization process and that a lading temperature above 185°F could actuate a PRD but not introduce oxygen into the tank and destabilize the VCM. The Oxy Vinyl representatives indicated that they had never had a VCM incident lead to a BLEVE.

Despite this new information from Oxy Vinyls, NS and its contractors continued to respond to the situation as though the VCM was polymerizing. About 5:45 p.m. on February 5, 2023, after the meeting with Oxy Vinyls' on-scene representatives, SPSI and SRS contacted the incident commander and said that circumstances might require a vent and burn. This action demonstrated a focus on polymerization to the exclusion of alternatives even after Oxy Vinyls employees' initial judgment that polymerization was unlikely, and it ignored contradictory evidence: between 5:00 p.m. and 6:00 p.m., the measured temperature of the suspect tank car had fallen 2°F. The temperature continued to trend downward over the next day, as shown in figure 32. NS and its contractors continued to assert the necessity of a vent and burn when Oxy Vinyls' expert opinions and on-scene evidence should have led them to question their original focus on polymerization.

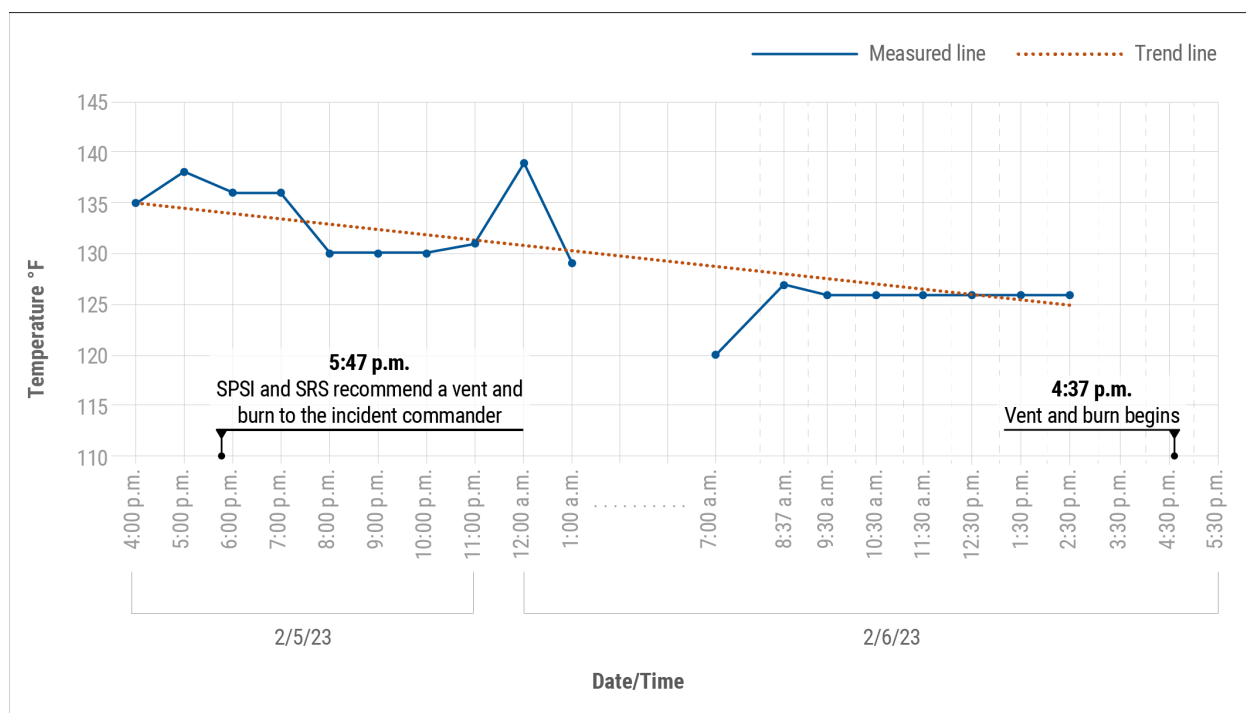


Figure 32. Tank car OCPX80370 temperature graph with vent and burn timing.

While NS and its contractors continued to advocate for a vent and burn, the on-scene Oxy Vinyls representatives conducted another conference call with the Oxy Vinyls team in Dallas. They reached a consensus that the available evidence did not indicate polymerization. By the time Oxy Vinyls met with SPSI at 7:00 p.m. on February 5, NS had begun preparations for the vent and burn. Oxy Vinyls shared its conclusions with SPSI, but SPSI did not reconsider its course of action, and neither SPSI nor NS shared Oxy Vinyls’ conclusions with the rest of the incident command. The NTSB concludes that NS and its contractors continued to assert the necessity of a vent and burn after expert opinion and available evidence should have led them to re-evaluate their initial conclusions regarding polymerization.

Throughout these meetings and conversations, Oxy Vinyls had no contact with the incident commander or elements of the incident command other than through NS, SRS, and SPSI. Oxy Vinyls personnel expected NS and its contractors to relay information to the rest of the incident command. However, Oxy Vinyls’ conclusions about the lack of polymerization were not relayed to the incident commander or other personnel in the incident command. There is no evidence that the incident command was aware that Oxy Vinyls was available as a source of expertise on VCM at any time up to the final vent and burn decision.

The incident commander, the EPFD fire chief, approved the vent and burn based on information from NS, SRS, and SPSI. The incident commander made his

decision after two meetings on the afternoon of February 6, 2023. The first meeting involved the wider incident command and participation from entities not formally part of the incident command, such as the governors of Ohio and Pennsylvania. The second, smaller meeting involved only the incident commander, the Ohio Governor, and representatives from NS, SRS, and SPSI. Oxy Vinyls was not invited to or present at either meeting, and no attendees questioned the NS position that dangerous polymerization was occurring in the VCM tank cars.

The NTSB is concerned by the absence of Oxy Vinyls' opinions and information from the decision-making process. At the NTSB's Investigative Hearing, the Oxy Vinyls technical manager testified that he was confident that Oxy Vinyls' opinions were being relayed to the full incident command, but NS and its contractors were not doing so.¹⁵⁶ During the second meeting on February 6, NS and its contractors told the incident commander that if the temperature in a tank car reached 153–158°F, the result would be an uncontrolled polymerization reaction.¹⁵⁷ This temperature range is not contained in the written guidance referenced during the emergency response and does not correspond to information that Oxy Vinyls shared with NS or its contractors. NS stated that if a tank car temperature reached 150°F, NS and its contractors would have to cease any efforts to prevent an explosion. NS also gave the incident commander a 13-minute time limit on his decision, claiming that the vent and burn needed to be conducted by 3:00 p.m. to finish in daylight and to avoid an atmospheric inversion that would hamper dispersion of the vapor cloud. The charges for the vent and burn were detonated at 4:37 p.m. following a series of delays, indicating that 3:00 p.m. was not a hard deadline for the procedure.

NS's communications with the incident commander produced a heightened sense of urgency around the vent and burn; the incident commander testified at the NTSB's Investigative Hearing that he had to make a decision quickly to avoid catastrophic failure of a tank car.¹⁵⁸ These communications included incomplete and inaccurate information that pushed the incident commander toward approving the vent and burn. The NTSB concludes that NS and its contractors compromised the integrity of the vent and burn decision by creating unwarranted urgency and not communicating expert opinions and information completely and accurately to the incident commander. Without Oxy Vinyls to share its determinations, the incident

¹⁵⁶ NTSB Investigative Hearing Transcript, Day 2, p. 253.

¹⁵⁷ At this time, temperature readings from the exterior of the hottest tank car, OCPX80370, were about 126°F and had been trending downward.

¹⁵⁸ NTSB Investigative Hearing Transcript, Day 2, p. 139.

commander did not have a basis to effectively question the immediate necessity of the vent and burn. The NTSB concludes that the absence of Oxy Vinyls' expertise from the formal incident command denied the incident commander relevant information necessary to make a fully informed decision about the vent and burn. The NTSB recommends that Oxy Vinyls develop a policy to ensure that expertise on chemicals manufactured and offered for transportation by Oxy Vinyls is communicated to and shared with the full incident command during transportation accidents or incidents. The NTSB also recommends that the American Chemistry Council and The Chlorine Institute advise their members of the circumstances of the East Palestine derailment and fire and the need for shippers to ensure their expertise is communicated to and shared with the full incident command.

Oxy Vinyls developed conclusions about polymerizations and shared them with NS and its contractors in the expectation that its expertise would be passed onto decision-makers and taken into consideration. The NTSB is concerned by NS's decision not to relay Oxy Vinyls' conclusions that contradicted its early judgements about polymerization to the incident commander. NS was aware of expert opinions that contradicted its own and those of its contractors and, by not relaying the information, denied the rest of the incident command a chance to weigh the dissenting opinions before making a final decision.

Several explanations for NS's sustained preference for the vent and burn are consistent with available evidence, including confirmation bias and the perceived safety risks of alternative means of unloading the VCM. The explanations presented here are possibilities, but the evidence did not support a determination of which of these explanations, if any, was the main reason for the sustained preference for the vent and burn.

Confirmation bias is defined by the American Psychological Association as "the tendency to gather evidence that confirms preexisting expectations, typically by emphasizing or pursuing supporting evidence while dismissing or failing to seek contradictory evidence" (American Psychological Association 2018). NS and its contractors arrived at a belief in the need for a vent and burn as early as the afternoon of February 4, and the subsequent pattern of dismissing contradictory evidence while interpreting ambiguous evidence as support for the original belief is consistent with confirmation bias. Confirmation bias does not explain NS's inaccurate communications with the incident commander, but it does account for NS's failure to use Oxy Vinyls' expertise effectively or to revise its original position as more facts became available.

On February 5, 2023, NS told the NTSB that it had considered and rejected alternative means of unloading the VCM tank cars: transloading, hot tapping, and flaring. Several tank cars had damaged fittings, such as melted aluminum components, that could have made transloading or flaring the VCM unsafe or impossible. Hot tapping would have required personnel to puncture the tank cars and work near damaged equipment during the unloading process, exposing personnel to risk. Of the alternatives considered on the scene, NS described the vent and burn as presenting the least safety risk to railroad personnel, which was one reason NS provided for preferring the vent and burn and using the procedure on all five VCM tank cars instead of only the tank car with an elevated temperature (OCPX80370).

However, NS overlooked an alternative option: allowing the tank cars to finish cooling, then taking additional time to complete an assessment of each tank car's condition. When interviewed by the NTSB, the incident commander said he had been informed that the positions of the tank cars meant that venting and burning one would pose a risk to the others, and that venting and burning all five simultaneously was appropriate as a safety precaution. But a sixth tank car, a derailed DOT-105 tank car carrying isobutylene, a flammable gas in the same hazard class and division as VCM, was located closer than the four cooler VCM tank cars to tank car OCPX80370. The isobutylene tank car was therefore also closer to the vent and burn procedure performed on OCPX80370. The isobutylene tank car was not vented and burned, and it was successfully moved on February 7 and transloaded on February 23 following a damage assessment, which suggests that the nearby vent and burn did not render it unsafe to handle or unload. By performing a vent and burn of all five VCM tank cars on February 6, NS denied itself the option of assessing the structural condition and fittings of the VCM tank cars with the same thoroughness it applied to the isobutylene tank car.

The NTSB concludes that, no explanation or argument for NS and its contractors' continued advocacy for the vent and burn procedure justifies failing to communicate relevant expertise and dissenting opinions to the incident commander. The NTSB recommends that NS develop a policy to ensure that the expertise of manufacturers and shippers of hazardous materials involved in transportation accidents or incidents is communicated to its on-scene representatives and contractors and shared with the full incident command.

2.5.4 Vent and Burn Criteria

The FRA recognizes the vent and burn method as a valid but high-risk last-resort procedure for unloading tank cars transporting at least certain compressed liquified flammable gases, as shown by its 1994 and 2007 guidance on the method. The second 2007 report (Phase II of the associated study) includes guidance on when a vent and burn should be considered, what commodities are candidates for the procedure, and how an incident command should approach the decision (FRA 2007a). At least one individual involved in the East Palestine emergency response had knowledge of the 2007 study and Phase II report; the NS regional hazardous materials manager, then employed by the AAR, was one of the contributing authors. However, there is no evidence that the specific guidance in the Phase II report was used during the vent and burn decision, and the incident commander was not aware of the report's existence. Even if he had known about the report, he would not have had ready access to it because of the report's status as Sensitive Security Information.

While it is unclear whether access to the Phase II report would have led the incident commander to a different decision, the report would have provided him with additional information and the tools needed to ask further questions of NS and its contractors. The Phase II report's guidance, cautions, and checklists would have provided the incident commander with additional knowledge and resources when deciding whether to approve the vent and burn. The presence of public, well-known criteria for when to attempt vent and burn procedures would also have provided a baseline for conversations among NS, its contractors, and the rest of the incident command.

On May 6, 2007, the FRA released publicly available versions of the Phase I and Phase II reports on its website, but web publication may not be sufficient to distribute this guidance. The 1994 handbook was available on the FRA's website at the time of the East Palestine derailment but was not consulted during the lead-up to the vent and burn. The NTSB is concerned that the FRA's most recent and complete guidance about when to attempt the vent and burn method has not been widely disseminated to emergency responders. A vent and burn procedure was not necessary in East Palestine to prevent a BLEVE, but what was true in East Palestine may not hold in other circumstances or for other products. The NTSB concludes that the significant local and environmental impacts of a vent and burn decision demonstrate the need for federal guidance about what products and circumstances are candidates for the vent and burn method. The NTSB recommends that the FRA distribute the public versions of its 2007 vent and burn reports to emergency responder associations, including the IAFC, IAFF, and NVFC. To increase awareness

of federal guidance, the NTSB recommends that the IAFC, IAFF, and NVFC advise their members of the circumstances surrounding the vent and burn at East Palestine, the importance of obtaining information from the shipper when considering a vent and burn, and the availability of federal guidance on when the vent and burn method may be appropriate.

While the 2007 reports contain useful guidance, they were developed before the East Palestine vent and burn and therefore do not incorporate lessons learned from that accident. The Phase II report does not advise an incident command to contact the shipper when considering a vent and burn, for example, instead directing the incident commander to a database that has not been widely distributed. The checklist provided in the Phase II report does not always clearly indicate how the answers to its questions should shape a vent and burn decision. For example, it includes a row for product viscosity (high, medium, or low) but does not clearly explain how an incident command can determine viscosities or how different viscosities will affect a vent and burn (FRA 2007a). The NTSB recommends that the FRA update and re-publish its 2007 vent and burn reports to include clear instructions to consult the shipper when considering a vent and burn, more comprehensive guidance on what products are candidates for a vent and burn along with what chemical and other hazards may result, and an updated process flow chart incorporating lessons from the East Palestine vent and burn; the re-published reports should identify the questions an incident commander should ask when considering a vent and burn, distinguish the meaning of the answers, and identify the resources necessary to make an informed decision. The NTSB also recommends that the FRA make the updated versions of the 2007 vent and burn reports described in R-24-8 available to emergency responder associations, including the IAFC, IAFF, and NVFC. The NTSB also recommends that PHMSA distribute the FRA's most current guidance on the vent and burn method to emergency response agencies by referencing it in the next edition of the ERG.

2.6 Locomotive Data Recorders

The lead locomotive of train 32N was equipped with both head-end and inward-facing image recorders that provided investigators with video and audio data detailing the crew's activities and actions in the moments leading up to and during the derailment. NS voluntarily installed these devices; image and audio recorders are not required by FRA regulations for freight locomotives. In this accident, the audio and video data demonstrated and confirmed that the crewmembers were alert and responded appropriately to the hot bearing alarm. Additionally, the data were instrumental in corroborating crew statements.

The NTSB has determined that many previous railroad accident investigations would have benefitted from this technology. In a number of these accidents, the operator was killed, seriously injured, or could not recall details moments before the accident. However, even in the cases where the operator was not injured, audio and image recorders could be used to help verify what might have been seen and what crew actions were taken during the accident sequence.

For example, audio and image recorders were beneficial to our investigation of the Amtrak passenger train 501 derailment in DuPont, Washington, on December 18, 2017 (NTSB 2019). In that accident, the locomotive was equipped with an inward-facing image recorder that provided both a visual and audio recording of the crewmember activities during the accident trip. The device was voluntarily installed, and the recorded information proved extremely useful in the NTSB investigation.

Further, image recordings were also beneficial to our investigations of the January 4, 2017, collision of two Southeastern Pennsylvania Transportation Authority trolleys in Philadelphia, Pennsylvania, and the April 3, 2016, Amtrak accident in Chester, Pennsylvania (NTSB 2018b, NTSB 2017c). In those accidents, as in East Palestine, investigators used the image recordings to gather additional pertinent information about the accident sequence and used the audio recordings to corroborate the statements made by the operating crews. In turn, this information was used to develop recommendations to improve the safety of train operations. These types of recorders are also critical to improving operational safety and management oversight.

Unfortunately, in many other railroad accidents, the NTSB has not been able to determine the actions of the crewmembers operating the train because of the lack of inward-facing image and audio recordings. In our investigation of the August 12, 2019, collision of two CSX Transportation freight trains near Carey, Ohio, the NTSB was unable to determine the actions of the westbound train's crewmembers when they were operating the train from Columbus, Ohio, to Carey, Ohio; the actions of the westbound train engineer operating alone in the locomotive cab; or the events leading up to the collision (NTSB 2020c). This collision again demonstrated the need for in-cab recording devices to better understand and thereby prevent serious railroad collisions.

Similar issues were found during the NTSB's investigation of the September 12, 2008, head-on collision in Chatsworth, California, between a Metrolink passenger train and a Union Pacific Railroad freight train (NTSB 2010). The NTSB was unable to determine the actions of the Metrolink engineer leading up to the collision, and after discovering some illicit activities by the train engineer during

previous trips, the NTSB determined that Metrolink had no way of monitoring the train engineer's activities to ensure appropriate behavior.

The Chatsworth collision, in which 25 people were killed and 102 people were injured, underscored the importance of understanding the activities of crewmembers in the time leading up to the collision. As a result of that investigation, on February 23, 2010, the NTSB issued Safety Recommendations R-10-1 and R-10-2 to the FRA:

Require the installation, in all controlling locomotive cabs and cab car operating compartments, of crash- and fire-protected inward- and outward-facing audio and image recorders capable of providing recordings to verify that train crew actions are in accordance with rules and procedures that are essential to safety as well as train conditions. The devices should have a minimum 12-hour continuous recording capability with recordings that are easily accessible for review, with appropriate limitations on public release, for the investigation of accidents or for use by management in carrying out efficiency testing and systemwide performance monitoring programs. (R-10-1)¹⁵⁹

Require that railroads regularly review and use in-cab audio and image recordings (with appropriate limitations on public release), in conjunction with other performance data, to verify that train crew actions are in accordance with rules and procedures that are essential to safety. (R-10-2)¹⁶⁰

In the 14 years since these recommendations were issued, the NTSB has reiterated them in the following seven major railroad accident investigations:

- September 30, 2010, collision of two Canadian National Railway freight trains near Two Harbors, Minnesota (NTSB 2013c)
- April 17, 2011, collision of a BNSF coal train with the rear end of a standing BNSF maintenance-of-way train in Red Oak, Iowa (NTSB 2012a)
- June 24, 2012, head-on collision of two Union Pacific Railroad freight trains near Goodwell, Oklahoma (NTSB 2013b)
- May 25, 2013, collision of a Union Pacific Railroad freight train with a BNSF Railway freight train near Chaffee, Missouri (NTSB 2014a)

¹⁵⁹ Safety Recommendation R-10-1 is currently classified Open–Unacceptable Response.

¹⁶⁰ Safety Recommendation R-10-2 is currently classified Open–Unacceptable Response.

- April 28, 2015, collision of two Southwestern Railroad freight trains near Roswell, New Mexico (NTSB 2018c)
- May 12, 2015, derailment of a National Railroad Passenger Corporation (Amtrak) passenger train in Philadelphia, Pennsylvania (NTSB 2016a)
- August 12, 2019, collision of two CSX Transportation freight trains near Carey, Ohio (NTSB 2020c)

Following the investigation of one of these accidents, the June 24, 2012, collision in Goodwell, Oklahoma, the NTSB made the following safety recommendation to all Class I railroads:

Install in all controlling locomotive cabs and cab car operating compartments crash- and fire-protected inward- and outward-facing audio and image recorders. The devices should have a minimum 12-hour continuous recording capability. (R-13-26)

In response to Safety Recommendation R-13-26, on December 10, 2014, NS informed us that it already used outward-facing image recorders, and that it was analyzing safety benefits, costs, and employee privacy concerns related to inward-facing image recorders. On May 4, 2015, we noted these efforts and encouraged NS to install the recommended inward-facing audio and image recorders. Pending completion of that action, Safety Recommendation R-13-26 was classified Open–Acceptable Response. On December 23, 2021, we followed up with NS on the status of implementation of the recommendation, but we have not yet received a reply. The lead locomotive involved in the East Palestine derailment was equipped with inward- and outward-facing image and audio recorders.

We issued R-13-26 to a total of seven Class I railroads. Of the remaining six Class I railroads, three have a status of Open–Acceptable Response, two have a status of Open–Unacceptable Response, and one has a status of Open–Await Response because the railroad has not yet responded. We are concerned that in over 10 years since we issued R-13-26, none of the Class I railroads has fully implemented this recommendation.

In response to Safety Recommendations R-10-1 and R-10-2, the FRA announced at a May 28, 2015, meeting of the Railroad Safety Advisory Committee that in the absence of Railroad Safety Advisory Committee consensus recommendations, the FRA was proceeding with an NPRM addressing mandatory installation of locomotive recording devices in both freight and passenger railroads. As a result, on September 29, 2015, Safety Recommendations R-10-1 and R-10-2 were classified Open–Acceptable Response.

The 2015 FAST Act required the Secretary of Transportation to promulgate, within 2 years after the date of the FAST Act, regulations to require each railroad carrier that provides regularly scheduled, intercity rail passenger or commuter rail passenger transportation to install inward- and outward-facing image recording devices in all controlling locomotive cabs and cab car operating compartments. However, the FRA did not develop regulations requiring that recording devices be installed in intercity rail passenger or commuter passenger transportation within the 2-year deadline.

In our May 2019 DuPont accident report, the NTSB concluded that:

The Federal Railroad Administration has demonstrated an unwillingness to implement the recommendations and regulation that would require inward-facing video and audio devices that are critical to accident investigations and improving safety on our nation's railroads. (NTSB 2019)

We further concluded that:

Inward-facing recorders with both image and audio capabilities can increase the understanding of the circumstances of an accident, and, ultimately, provide greater precision in safety recommendations and subsequent safety improvements.

Consequently, we issued the following recommendation to the Secretary of Transportation on June 21, 2019:

Require the Federal Railroad Administration to issue regulations for inward-facing recorders that include image and audio recordings as recommended by the National Transportation Safety Board in R-10-1 and R-10-2. (R-19-7)

We have yet to receive a response from the Secretary of Transportation and the recommendation remains classified Open–Await Response. On July 24, 2019, 9 years after we issued R-10-1 and R-10-2 and more than a year and a half after the FAST Act required regulatory action, the FRA published an NPRM, titled “Locomotive Image and Audio Recording Devices for Passenger Trains,” proposing a requirement to install inward- and outward-facing recorders in passenger trains (84 Fed. Reg. 35712). The NPRM was only partially responsive to the NTSB recommendations because it did not apply to freight railroads.

On September 16, 2019, the NTSB stated the following in response to the NPRM:

Freight trains and passenger trains operate on the same railroad tracks, posing the risk of accidents that have the potential to significantly affect the public. From a safety management system perspective, it is probable that recorded information about safety problems identified in freight railroad accidents and incidents could inform, mitigate, or prevent similar safety problems that might potentially affect passenger railroad operations. As a result, we believe it would be shortsighted to limit the proposed rule to passenger railroads. The FRA should ensure one level of safety for both passenger and freight railroads. Further, we firmly believe any such devices that railroads have already voluntarily installed, whether on freight or passenger trains, should be required to meet the minimum standards in the final rule.

Of the seven reiterations since we issued R-10-1 and R-10-2, six have involved collisions of freight trains.

In our 2020 Carey report, we concluded that “inward- and outward-facing recorders can improve the quality of accident and incident investigations and provide the opportunity for proactive steps by railroad management to verify that train crew actions are in accordance with safety rules and procedures” (NTSB 2020c). As a result, we reiterated Safety Recommendations R-10-1 and R-10-2 to the FRA. Because it had been 10 years since the recommendations were issued and the FRA had begun to address only passenger railroads, and not freight railroads, Safety Recommendations R-10-1 and R-10-2 were classified Open–Unacceptable Response.

On October 12, 2023, the FRA published the final rule, “Locomotive Image and Audio Recording Devices for Passenger Trains,” amending 49 *CFR* Parts 217, 218, 229, and 299. The FRA rule requires installation of inward- and outward-facing locomotive image recording devices on all lead locomotives in passenger trains, as required by the FAST Act. The FRA declined to require freight railroads to install recording devices at the time of the rulemaking, saying the statutory requirements at 49 *United States Code* 20168(a) did not apply to freight locomotives (88 Fed. Reg. 70722). The rule falls short of our recommendations because it fails to require audio recording and excludes freight rail from any requirements. More than 14 years have passed since we recommended that the FRA require audio and image recorders in all locomotives, whether on freight or passenger trains. The recommendations were prompted by railroad accident investigations in which the NTSB determined having inward- and outward-facing audio and image recorders would have provided crucial

information to the railroads, their workforces, the FRA, and the NTSB that could have improved safety. In a number of those accidents, the operator died, was seriously injured, or could not recall details from moments before the accident.

Inward- and outward-facing audio and image recorders that are crash- and fire-protected provide valuable information about the events leading up to and during an accident in determining why it occurred. In this case, inward-facing image and audio data were instrumental in eliminating the train crew's performance as a factor in the accident. Further, recorded image and audio information allows railroads, labor unions, the FRA, and the NTSB to identify and immediately address critical improvements that directly impact the safety of the rail industry, the traveling public, and the communities in which our railroads operate. The NTSB concludes that inward- and outward-facing recorders can improve the quality of accident and incident investigations and provide the opportunity for proactive steps by railroad management to verify that train crew actions are in accordance with safety rules and procedures. Therefore, the NTSB reiterates Safety Recommendation R-13-26 to the Class I railroads.

The NTSB believes that the FRA has the regulatory authority to establish regulations to act on Safety Recommendations R-10-1 and R-10-2. The relevant language in the FAST Act mandated that the FRA require image recorders for passenger and commuter trains but did not modify the FRA's existing authority to establish requirements for rail equipment, including image and audio recorders, to improve safety. However, we note that the FRA's rulemaking on image recorders resulted from a specific legislative mandate to act, and we believe that a legislative mandate to act on Safety Recommendations R-10-1 and R-10-2 would result in the FRA satisfying these long-standing recommendations. Therefore, the NTSB recommends that the FRA require the installation, in all controlling locomotive cabs and cab car operating compartments, of crash and fire protected inward- and outward-facing audio and image recorders capable of providing recordings to verify that train crew actions are in accordance with rules and procedures that are essential to safety as well as train conditions. The devices should have a minimum 12-hour continuous recording capability with recordings that are easily accessible for review, with appropriate limitations on public release, for the investigation of accidents or for use by management in carrying out efficiency testing and systemwide performance monitoring programs. If necessary, obtain legislative authority to act on this recommendation. The NTSB also recommends that the FRA require that railroads regularly review and use in-cab audio and image recordings (with appropriate limitations on public release), in conjunction with other performance data, to verify that train crew actions are in accordance with rules and procedures that are essential

to safety. If necessary, obtain legislative authority to act on this recommendation. Safety Recommendations R-10-1 and R-10-2 are classified Closed–Superseded.

Finally, the NTSB concludes that the FRA’s final rule in response to the FAST Act did not require audio recording in passenger locomotives and did not require inward- and outward-facing image and audio recording in freight rail locomotives, resulting in a missed opportunity to record important safety data. As noted above, the FAST Act did not directly mandate that the FRA establish regulations that would satisfy Safety Recommendations R-10-1 and R-10-2, and the FRA’s October 2023 rulemaking did not address all the safety concerns raised by the NTSB. Therefore, the NTSB recommends that the Secretary of Transportation require the FRA to issue regulations for inward-facing recorders that include image and audio recordings as recommended by the NTSB in R-24-10 and R-24-11. If necessary, obtain legislative authority to act on this recommendation. Safety Recommendation R-19-7 is classified Closed–Superseded.

3 Conclusions

3.1 Findings

1. None of these issues contributed to the derailment of train 32N and subsequent hazardous materials release: (1) defects in railroad track or infrastructure; (2) the signals or train control system; (3) the train crew's proper train handling and appropriate response to the bearing alarm and derailment; (4) the marking, placarding, and method of loading for the derailed vinyl chloride monomer tank cars; (5) the weight and lading volume of the derailed hazardous materials tank cars; and (6) the mechanical crashworthiness of the derailed DOT-105 tank cars.
2. Train 32N derailed because the L1 bearing on railcar GPLX75465 overheated and caused the axle to separate, causing the railcar's lead truck to derail.
3. There is insufficient evidence to determine if the Terminal Railroad Association of St. Louis mechanical inspection of train 32N on February 1, 2023, failed to identify signs of failure on hopper car GPLX75465's L1 wheel bearing.
4. The non-critical alert transmitted by the Salem, Ohio, hot bearing detector did not reflect the true temperature and failing condition of the L1 wheel bearing.
5. A failing wheel bearing's actual internal temperatures will likely exceed external temperatures measured and reported by a hot bearing detector (HBD), and this limit on HBD accuracy is inherent in how current HBDs and railcar trucks are designed.
6. The combination of Norfolk Southern Railway standard operating procedures that required only continued monitoring for non-critical bearing alerts, the limited ability of hot bearing detectors to measure a bearing's actual internal temperature, and the distance between detectors did not give the train's crew adequate warning to stop the train before the suspect bearing failed and caused the derailment.
7. Without research into how differences in alert and alarm thresholds and varied distances between detectors affect the performance of wayside bearing defect detection systems, railroads and regulators lack the

information to determine what changes would produce significant safety improvements.

8. Regulatory requirements for the installation, inspection, and maintenance of wayside bearing defect detectors would protect the reliability of these devices and improve the safety of railroad operations.
9. Because the effectiveness of wayside bearing defect detection systems depends on appropriate operational responses, and because the rail industry has yet to arrive at a consensus standard for these responses, research is necessary to determine what operational responses to bearing alerts and alarms are sufficient to prevent bearing-related accidents.
10. A database capturing bearing failure and replacement information could help identify what factors pose an increased risk of burn-off so that railroads, regulators, and investigators can better address bearing-related safety issues.
11. While the East Palestine Fire Department deputy fire chief and other volunteer firefighters acted in good faith to protect their community, the initial emergency response did not conform to Emergency Response Guidebook guidance for fires involving tank cars and unknown materials; both the proximity of the first command post to the fire and the use of manned hoses near a fire involving unknown materials placed these firefighters at unnecessary risk.
12. The state of Ohio's statutory requirements for volunteer firefighter training were insufficient to support a safe emergency response to the East Palestine derailment led by a volunteer fire department.
13. Because there were not common radio channels between all responding agencies, the emergency response lacked efficient coordination.
14. The delayed transmittal of consist information by Norfolk Southern Railway to emergency responders needlessly increased the time emergency responders spent near the derailment pileup and delayed the evacuation order, resulting in unnecessary and increased exposure of emergency responders and the public to postderailment hazards.
15. The Pipeline and Hazardous Materials Safety Administration's Hazardous Materials: FAST Act Requirements for Real-Time Train Consist Information addresses the safety concerns of Safety Recommendation R-07-4.

16. The vulnerability of tank car placards to fire exposure resulted in illegible placards and hampered emergency responders' efforts to identify hazards.
17. The postderailment fire likely began with hazardous material released from a mechanically breached DOT-111 tank car, most probably the butyl acrylates released from tank car UTLX205907.
18. If DOT-111 tank cars transporting combustible and flammable liquids had not sustained mechanical breaches during the derailment, the DOT-105 tank cars transporting vinyl chloride monomer likely would not have been exposed to the fire conditions that led to concerns about polymerization and ultimately the vent and burn actions that released additional lading from those five DOT-105 tank cars.
19. Voluntary industry action to improve the safety of the tank car fleet by completing the phase out of remaining DOT-111 tank cars in flammable liquids service ahead of the Fixing America's Surface Transportation Act mandate is feasible, but such action is unlikely because of economic and business disincentives.
20. The presence of DOT-111 tank cars carrying hazardous materials in a mixed freight train increases the risk of lading releases from other, more resilient tank cars during a derailment.
21. The current Association of American Railroads tank car certificate of construction approval process lacks a means of verifying manufacturers' claims and is therefore insufficient to ensure that tank cars and their fittings are appropriate for their specified lading.
22. While the use of aluminum in the vinyl chloride monomer tank cars and pressure relief devices rendered them susceptible to thermal damage, there is insufficient evidence to determine whether this greater susceptibility created a safety hazard or contributed to the release of hazardous materials following the East Palestine derailment.
23. Cascading hazardous materials releases are not unique to high-hazard flammable trains, and the probability of a cascading hazardous materials release depends in part on variations in tank car survivability and on the presence of hazardous materials other than Class 3 flammable liquids, such as combustible liquids and Division 2.1 flammable gases.

24. The definition of key train in Association of American Railroads Circular OT-55 does not account for differences in survivability between different tank car specifications, and the DOT-111 and AAR-211 specifications can pose an elevated risk of a hazardous materials release compared to other specifications, such as the DOT-117.
25. Postaccident examinations, which found no solidified chemical matter blocking pressure relief devices and other tank car service equipment openings, do not indicate that a polymerization reaction occurred within any of the five vinyl chloride monomer tank cars.
26. The observed downward temperature trend in tank car OCPX80370 indicates that polymerization was not occurring within the tank car, contrary to the representation by Norfolk Southern Railway and its contractors.
27. The vinyl chloride monomer within the derailed DOT-105 tank cars remained in a stabilized environment until the vent and burn and did not undergo polymerization; the vent and burn procedure was not necessary to prevent a polymerization-induced tank rupture.
28. Language in The Chlorine Institute's Pamphlet 171 overstates the probability of vinyl chloride monomer polymerization in scenarios where tank cars remain intact, likely leading those using the pamphlet during an emergency response effort to overestimate the likelihood of polymerization.
29. Because Level 3 CHLOREP contractors are expected to provide advanced emergency response capabilities, including communicating expertise to other on-scene personnel and the transloading of vinyl chloride monomer (VCM), these contractors should possess or know how to obtain enough technical knowledge to accurately assess how chemical hazards, such as polymerization, affect a safe response to a VCM incident.
30. Information collected during real-world accidents is a vital resource in ensuring that hazardous materials guidance is suitable for supporting responses to transportation emergencies.
31. Norfolk Southern Railway and its contractors continued to assert the necessity of a vent and burn after expert opinion and available evidence should have led them to re-evaluate their initial conclusions regarding polymerization.

32. Norfolk Southern Railway and its contractors compromised the integrity of the vent and burn decision by creating unwarranted urgency and not communicating expert opinions and information completely and accurately to the incident commander.
33. The absence of Oxy Vinyls' expertise from the formal incident command denied the incident commander relevant information necessary to make a fully informed decision about the vent and burn.
34. No explanation or argument for Norfolk Southern Railway and its contractors' continued advocacy for the vent and burn procedure justifies failing to communicate relevant expertise and dissenting opinions to the incident commander.
35. The significant local and environmental impacts of a vent and burn decision demonstrate the need for federal guidance about what products and circumstances are candidates for the vent and burn method.
36. Inward- and outward-facing recorders can improve the quality of accident and incident investigations and provide the opportunity for proactive steps by railroad management to verify that train crew actions are in accordance with safety rules and procedures.
37. The Federal Railroad Administration's final rule in response to the Fixing America's Surface Transportation Act did not require audio recording in passenger locomotives and did not require inward- and outward-facing image and audio recording in freight rail locomotives, resulting in a missed opportunity to record important safety data.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the derailment involving Norfolk Southern Railway train 32N was the failure of the L1 bearing on the 23rd railcar in the consist that overheated and caused the axle to separate, derailing the train and leading to a postderailment fire that likely began with the release of a Class 3 flammable liquid from a DOT-111 tank car that was punctured during the derailment. Contributing to the postderailment fire and the severity of the hazardous materials release was the continued use of DOT-111 tank cars in hazardous materials service. Also contributing to the severity of the hazardous materials release were (1) the failure of Norfolk Southern Railway and its contractors to communicate relevant expertise and dissenting opinions to the incident

commander and (2) the inaccurate representation by Norfolk Southern Railway and its contractors that the tank cars were at risk of catastrophic failure from a polymerization reaction, which created unwarranted urgency and led to the unnecessary decision to vent and burn five derailed vinyl chloride monomer tank cars to prevent a polymerization-induced tank car rupture. Contributing to the exposure of emergency responders and the public to postderailment hazards were (1) Norfolk Southern Railway's delay in transmitting the train consist information to emergency responders and (2) the state of Ohio's insufficient training requirements for volunteer firefighters.

4 Recommendations

4.1 New Recommendations

As a result of this investigation, the National Transportation Safety Board makes the following new safety recommendations.

To the Secretary of Transportation:

Require the Federal Railroad Administration to issue regulations for inward-facing recorders that include image and audio recordings as recommended by the National Transportation Safety Board in R-24-10 and R-24-11. If necessary, obtain legislative authority to act on this recommendation. (R-24-1)

To the Federal Railroad Administration:

Research the effectiveness of current bearing defect detection systems, identify minimum standards to protect railroad personnel and the public, and make public the results of this research. (R-24-2)

Use the results of the research described in R-24-2 to develop and establish minimum requirements for bearing defect detection systems, including criteria for bearing alert and alarm thresholds and maximum distances between wayside detectors. (R-24-3)

Establish requirements for the installation, inspection, and maintenance of wayside bearing defect detectors to protect the reliability of these devices and improve the safety of railroad operations. (R-24-4)

Use the results of the research described in R-24-2 to develop and establish rules governing railroads' operational responses to bearing alerts and alarms. (R-24-5)

Monitor the progress of the Association of American Railroads' (AAR) action on R-24-20 and use your regulatory authority to ensure that the AAR addresses weaknesses in its tank car service equipment approval process. (R-24-6)

Distribute the public versions of your 2007 vent and burn reports to emergency responder associations, including the International Association of Fire Chiefs, the International Association of Fire Fighters, and the National Volunteer Fire Council. (R-24-7)

Update and re-publish your 2007 vent and burn reports to include clear instructions to consult the shipper when considering a vent and burn, more comprehensive guidance on what products are candidates for a vent and burn along with what chemical and other hazards may result, and an updated process flow chart incorporating lessons from the East Palestine vent and burn; the re-published reports should identify the questions an incident commander should ask when considering a vent and burn, distinguish the meaning of the answers, and identify the resources necessary to make an informed decision. (R-24-8)

Make the updated versions of the 2007 vent and burn reports described in R-24-8 available to emergency responder associations, including the International Association of Fire Chiefs, the International Association of Fire Fighters, and the National Volunteer Fire Council. (R-24-9)

Require the installation, in all controlling locomotive cabs and cab car operating compartments, of crash and fire protected inward- and outward-facing audio and image recorders capable of providing recordings to verify that train crew actions are in accordance with rules and procedures that are essential to safety as well as train conditions. The devices should have a minimum 12-hour continuous recording capability with recordings that are easily accessible for review, with appropriate limitations on public release, for the investigation of accidents or for use by management in carrying out efficiency testing and systemwide performance monitoring programs. If necessary, obtain legislative authority to act on this recommendation. (R-24-10)

Require that railroads regularly review and use in-cab audio and image recordings (with appropriate limitations on public release), in conjunction with other performance data, to verify that train crew actions are in accordance with rules and procedures that are essential to safety. If necessary, obtain legislative authority to act on this recommendation. (R-24-11)

To the Pipeline and Hazardous Materials Safety Administration:

Require that placards be able to survive fires and accidents and remain legible during such emergencies long enough to fulfill their functions as described in the Emergency Response Guidebook. (I-24-1)

Obtain the necessary legislative authority and accelerate the deadline for removing specification DOT-111 tank cars from flammable liquids service. (R-24-12)

Establish a tank car replacement schedule whereby non-pressure tank cars in any hazardous materials service must meet or exceed the safety standards of the DOT-117 specification; if necessary, obtain legislative authority to act on this recommendation. (R-24-13)

Revise the definition of high-hazard flammable train to account for differences in survivability between tank car specifications and to include hazardous materials other than flammable liquids, such as combustible liquids and Division 2.1 flammable gases, that can contribute to cascading hazardous materials releases; if necessary, obtain legislative authority to act on this recommendation. (R-24-14)

Distribute the Federal Railroad Administration's most current guidance on the vent and burn method to emergency response agencies by referencing it in the next edition of the Emergency Response Guidebook. (R-24-15)

To the state of Ohio:

Amend your firefighter training statute and revise your volunteer firefighter certification standards to meet the NFPA 1010 standard for professional firefighters. (R-24-16)

To the Columbiana County Emergency Management Agency:

Adopt a policy to, upon receipt of a train consist, immediately provide it to the incident commander and all appropriate response agencies and departments. (R-24-17)

Update your Emergency Operations Plan, Hazardous Materials Response Plan, and Hazard Mitigation Plan, as appropriate, with lessons learned from the East Palestine derailment and fire, including, at a minimum, coordination among response agencies, communications, requests for and distribution of the train consist, staging and availability of equipment and other resources, and training for emergency responders. (R-24-18)

To the Association of American Railroads:

Develop a database of bearing failures and replacements and make it available to railroads, regulators, and investigators to help determine and address failure risk factors. (R-24-19)

Revise the Manual of Standards and Recommended Practices, M-1002, Specifications for Tank Cars, to establish criteria and procedures for

manufacturers of tank car service equipment to demonstrate compatibility of pressure relief devices and other Association of American Railroads-approved service equipment with intended loadings. (R-24-20)

Revise the definition of key train in Circular OT-55 to designate as a key train any train containing tank cars transporting hazardous materials that do not meet the DOT-117 standard. (R-24-21)

To the National Volunteer Fire Council:

Identify barriers to adequate fire and emergency response training for volunteer firefighters, particularly for situations where hazardous materials are present, and publish actions states, municipalities, and the private sector can take to provide the flexibility necessary for volunteer firefighters to obtain training. (R-24-22)

To the International Association of Fire Chiefs, the International Association of Fire Fighters, and the National Volunteer Fire Council:

Advise your members of the circumstances of the East Palestine derailment and fire, identify fire departments whose personnel are not trained to the NFPA 1010 standard for professional firefighters, recommend that these departments adopt training that meets this standard, and inform them of funded training opportunities available through private, state, and federal programs. (R-24-23)

Advise your members of the circumstances surrounding the vent and burn at East Palestine, the importance of obtaining information from the shipper when considering a vent and burn, and the availability of federal guidance on when the vent and burn method may be appropriate. (R-24-24)

To The Chlorine Institute:

Review and revise Pamphlet 171 to ensure that its safety messages about vinyl chloride monomer polymerization in tank cars are accurate and adequately support determining whether a rail accident poses a risk of polymerization. (R-24-25)

Review and revise your Chlorine Emergency Plan training and verification programs to ensure that Level 3 contractors possess or can obtain enough technical knowledge of vinyl chloride monomer (VCM) to

accurately assess and respond to chemical hazards like polymerization during a VCM incident. (R-24-26)

To the American Chemistry Council and The Chlorine Institute:

Advise your members of the circumstances of the East Palestine derailment and fire and the need for shippers to ensure their expertise is communicated to and shared with the full incident command. (R-24-27)

To Norfolk Southern Railway:

Review and revise your procedures to immediately provide emergency responders with an accurate copy of the train consist upon becoming aware of an accident. (R-24-28)

Update your submissions to the Pipeline and Hazardous Materials Safety Administration's Incident Database to accurately reflect the cause of package failures following the East Palestine derailment. (R-24-29)

Adopt policies to ensure that your emergency response contractors keep detailed records of information used to make decisions involving hazardous materials, and share this information with shippers, relevant chemical associations, and other entities that provide hazardous materials guidance. (R-24-30)

Develop a policy to ensure that the expertise of manufacturers and shippers of hazardous materials involved in transportation accidents or incidents is communicated to your on-scene representatives and contractors and shared with the full incident command. (R-24-31)

To Oxy Vinyls, LP:

Update the safety data sheet for vinyl chloride monomer (VCM) to accurately reflect the potential risks of VCM and the hazards that increase such risks. (R-24-32)

Develop a policy to ensure that expertise on chemicals manufactured and offered for transportation by Oxy Vinyls is communicated to and shared with the full incident command during transportation accidents or incidents. (R-24-33)

4.2 Previously Issued Recommendations Reiterated in this Report

The National Transportation Safety Board reiterates the following safety recommendations.

To the Class I railroads:

Install in all controlling locomotive cabs and cab car operating compartments crash- and fire-protected inward- and outward-facing audio and image recorders. The devices should have a minimum 12-hour continuous recording capability. (R-13-26)

4.3 Previously Issued Recommendations Classified in this Report

The National Transportation Safety Board classifies the following safety recommendations.

To the Secretary of Transportation:

Require the Federal Railroad Administration to issue regulations for inward-facing recorders that include image and audio recordings as recommended by the National Transportation Safety Board in R-10-1 and R-10-2. (R-19-7)

Safety Recommendation R-19-7 is classified Closed–Superseded in section 2.6 of this report.

To the Federal Railroad Administration:

Require the installation, in all controlling locomotive cabs and cab car operating compartments, of crash- and fire-protected inward- and outward-facing audio and image recorders capable of providing recordings to verify that train crew actions are in accordance with rules and procedures that are essential to safety as well as train conditions. The devices should have a minimum 12-hour continuous recording capability with recordings that are easily accessible for review, with appropriate limitations on public release, for the investigation of accidents or for use by management in carrying out efficiency testing and systemwide performance monitoring programs. (R-10-1)

Safety Recommendation R-10-1 is classified Closed–Superseded in section 2.6 of this report.

Require that railroads regularly review and use in-cab audio and image recordings (with appropriate limitations on public release), in conjunction with other performance data, to verify that train crew actions are in accordance with rules and procedures that are essential to safety. (R-10-2)

Safety Recommendation R-10-2 is classified Closed–Superseded in section 2.6 of this report.

To the Pipeline and Hazardous Materials Safety Administration:

With the assistance of the Federal Railroad Administration, require that railroads immediately provide to emergency responders accurate, real-time information regarding the identity and location of all hazardous materials on a train. (R-07-4)

Safety Recommendation R-07-4 is classified Closed–Acceptable Action in section 2.3.2 of this report.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

JENNIFER HOMENDY
Chair

MICHAEL GRAHAM
Member

THOMAS CHAPMAN
Member

ALVIN BROWN
Member

J. TODD INMAN
Member

Report Date: June 25, 2024

Board Member Statements

Member Thomas Chapman filed the following concurring statement on July 2, 2024. Chair Jennifer Homendy and Member Alvin Brown joined in this statement.

I concur and join in the Board's unanimous adoption of the investigation report.

A key finding in the report notes that *"Norfolk Southern Railway and its contractors continued to assert the necessity of a vent and burn after expert opinion and available evidence should have led them to re-evaluate their initial conclusions regarding polymerization."*

Further, *"Norfolk Southern Railway and its contractors compromised the integrity of the vent and burn decision by creating unwarranted urgency and not communicating expert opinions and information completely and accurately to the incident commander."*

Finally, *"[n]o explanation or argument for Norfolk Southern Railway and its contractors' continued advocacy for the vent and burn procedure justifies failing to communicate relevant expertise and dissenting opinions to the incident commander."*

In the wake of the derailment, the hazardous materials release, and the subsequent fire, the community of East Palestine, Ohio, was further traumatized by the flawed decision to conduct a rare vent and burn procedure on five hazardous materials tank cars carrying vinyl chloride monomer. Undoubtedly, there will be long-term economic harm to the community. And some fear the massive vent and burn event will result in potential health or environmental impacts which may not be fully understood for years to come.

Our investigation confirmed that the vent and burn procedure was not necessary to prevent a polymerization-induced tank rupture of any of the five tank cars carrying vinyl chloride monomer. There was sufficient information and expertise available at the time to conclude that the vent and burn was unnecessary. Sadly, the decision was made without knowledge of dissenting opinions and evidence indicating that polymerization was not occurring.

Lessons must be learned from the chaotic process which led to the erroneous decision to vent and burn. Never again should any community suffer the pain of East Palestine.

Member J. Todd Inman filed the following concurring statement on July 2, 2024.

Commentary on Recommendations

Upon review of the investigatory material and draft report put together by NTSB staff, it became apparent how many similarities there were in this Norfolk Southern train 32N derailment to previous accidents the NTSB has investigated going back several decades. Unfortunately, while the NTSB issued numerous recommendations following those investigations, many remained incomplete or were closed-unacceptable that could have had a meaningful impact on February 3, 2023, and the days that followed. Examples include the phase-out of DOT-111 tank cars and the need for inward- and outward- facing recorders capable of at least 12 hours of recording.

Another area that was scrutinized by the investigation and found to have contributed to the inadequate and unsafe incident response was the lack of timely access to the train consist for first responders. In 2007, the Board recommended the Federal Railroad Administration (FRA) issue a requirement that railroads immediately provide emergency responders with accurate and real-time information regarding hazardous materials on a train. One day before the Board met, the Pipeline and Hazardous Materials Safety Administration (PHMSA) finally issued a regulation implementing this recommendation. While such a regulation would have made a difference for this accident, I am hopeful future accident responders will benefit from this regulation that was far overdue.

What the traveling public cannot afford is inaction on the recommendations issued and reiterated in response to this investigation. I would encourage each entity that received a recommendation to work with our Office of Safety Recommendations and Communications to find the quickest way to make meaningful progress towards the implementation of the Board's recommendations. While my amendment to recommendation #1 was not adopted, I implore the FRA to quickly identify a vehicle by which the research described under the recommendation can be conducted with haste, like an existing contract with a recognized research entity. I will also take the opportunity to advocate that the FRA, and any entity selected to conduct such research, ensure the research is not limited to current technologies in use in rail, but also explores other systems and technologies under development or in use in other fields that may have the ability to improve the accuracy of bearing detection, especially across varying car designs.

Commentary on the Purpose of NTSB Investigations

While the original purpose of reserving the opportunity to submit a Board Member Statement was to further highlight the importance of the recommendations of the report, I would be remiss if the opportunity was not also taken to remind the agency and future parties as a whole that we are entrusted by the public to investigate accidents, determine a probable cause, and issue recommendations that will improve transportation for the general public. As our regulations state “NTSB investigations are fact-finding proceedings with no adverse parties... and are not conducted for the purpose of determining the rights, liabilities, or blame of any person or entity, as they are not adjudicatory proceedings.”¹⁶¹ It is a difficult line to draw, but one that we need to be careful of never blurring as we deal with entities and individuals that may not elevate safety improvement in the manner we do, that hinder or hamper the work of our investigators, and that do not abide by the expectations of the NTSB.

My fear is that some of the comments made in connection to the Board Meeting and underlying investigation were not in response to information documented in our report or the accident itself and may have overshadowed the important content of the report, the work of the NTSB’s investigators, and the attention our recommendations deserve. While some discussion may have been warranted regarding alleged breaches of the party agreement and the impact it may have had on our staff and the investigation, the party system has proven to be effective over the 57-year history of the NTSB. The party system must be preserved to ensure we continue to receive the engagement necessary from industry and regulators that allows us to effectuate change in the transportation system. It is our responsibility to protect the party system in order to keep the public safe and it is the responsibility of the parties to embrace it. This requires respect and good faith by all participants and avoiding the placement of blame by parties or the NTSB at any point.

¹⁶¹ 49 CFR § 831.4(c)

Appendixes

Appendix A: Investigation

The National Transportation Safety Board (NTSB) was notified on February 3, 2023, of the derailment of Norfolk Southern Railway train 32N. The train was carrying several hazardous materials, and breached tank cars released hazardous materials and ignited. The incident commander later decided to deliberately breach five hazardous materials tank cars because of concerns that chemical reactions in at least one tank car could result in an explosion. No injuries were reported.

The NTSB launched Member Michael Graham, an investigator in charge, and a team to investigate the cause of the derailment, the hazardous materials release, and the emergency response.

Parties to the investigation included the Pipeline and Hazardous Materials Safety Administration; Federal Railroad Administration; Ohio State Highway Patrol; Village of East Palestine; Norfolk Southern Corporation; Trinity Industries Leasing Company; Oxy Vinyls, LP; GATX Corporation (owner of an involved tank car and the first hopper car to derail); Midland Manufacturing (a manufacturer of tank car fittings); Brotherhood of Locomotive Engineers and Trainmen; Transportation Communications Union; Brotherhood of Railway Carmen; International Association of Sheet Metal, Air, Rail and Transportation Workers; and International Association of Firefighters.

Appendix B: Consolidated Recommendation Information

Title 49 *United States Code* 1117(b) requires the following information on the recommendations in this report.

For each recommendation—

(1) a brief summary of the Board’s collection and analysis of the specific accident investigation information most relevant to the recommendation;

(2) a description of the Board’s use of external information, including studies, reports, and experts, other than the findings of a specific accident investigation, if any were used to inform or support the recommendation, including a brief summary of the specific safety benefits and other effects identified by each study, report, or expert; and

(3) a brief summary of any examples of actions taken by regulated entities before the publication of the safety recommendation, to the extent such actions are known to the Board, that were consistent with the recommendation.

To the Secretary of Transportation

R-24-1

Require the Federal Railroad Administration to issue regulations for inward-facing recorders that include image and audio recordings as recommended by the National Transportation Safety Board in R-24-10 and R-24-11. If necessary, obtain legislative authority to act on this recommendation.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.6, Locomotive Data Recorders. Information supporting (b)(1) can be found on pages 158-65; (b)(2) and (b)(3) are not applicable.

To the Federal Railroad Administration

R-24-2

Research the effectiveness of current bearing defect detection systems, identify minimum standards to protect railroad personnel and the public, and make public the results of this research.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.2.4, Bearing Failure Detection. Information supporting (b)(1) can be found on pages 103-08; (b)(2) can be found on pages 107-08; and (b)(3) is not applicable.

R-24-3

Use the results of the research described in R-24-2 to develop and establish minimum requirements for bearing defect detection systems, including criteria for bearing alert and alarm thresholds and maximum distances between wayside detectors.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.2.4, Bearing Failure Detection. Information supporting (b)(1) can be found on pages 103-08; (b)(2) can be found on pages 107-08, and (b)(3) is not applicable.

R-24-4

Establish requirements for the installation, inspection, and maintenance of wayside bearing defect detectors to protect the reliability of these devices and improve the safety of railroad operations.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.2.4, Bearing Failure Detection. Information supporting (b)(1) can be found on pages 109-10; (b)(2) and (b)(3) are not applicable.

R-24-5

Use the results of the research described in R-24-2 to develop and establish rules governing railroads' operational responses to bearing alerts and alarms.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.2.4, Bearing Failure Detection. Information supporting (b)(1) can be found on page 110; (b)(2) and (b)(3) are not applicable.

R-24-6

Monitor the progress of the Association of American Railroads' (AAR) action on R-24-20 and use your regulatory authority to ensure

that the AAR addresses weaknesses in its tank car service equipment approval process.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4.3.1, Tank Car and Fittings Certification. Information supporting (b)(1) can be found on pages 135-36; (b)(2) and (b)(3) are not applicable.

R-24-7

Distribute the public versions of your 2007 vent and burn reports to emergency responder associations, including the International Association of Fire Chiefs, the International Association of Fire Fighters, and the National Volunteer Fire Council.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.5.4, Vent and Burn Criteria. Information supporting (b)(1) can be found on pages 157-58; (b)(2) can be found on pages 157-58; and (b)(3) is not applicable.

R-24-8

Update and re-publish your 2007 vent and burn reports to include clear instructions to consult the shipper when considering a vent and burn, more comprehensive guidance on what products are candidates for a vent and burn along with what chemical and other hazards may result, and an updated process flow chart incorporating lessons from the East Palestine vent and burn; the re-published reports should identify the questions an incident commander should ask when considering a vent and burn, distinguish the meaning of the answers, and identify the resources necessary to make an informed decision.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.5.4, Vent and Burn Criteria. Information supporting (b)(1) can be found on pages 157-58; (b)(2) can be found on pages 157-58; and (b)(3) is not applicable.

R-24-9

Make the updated versions of the 2007 vent and burn reports described in R-24-8 available to emergency responder associations, including the International Association of Fire Chiefs, the

International Association of Fire Fighters, and the National Volunteer Fire Council.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.5.4, Vent and Burn Criteria. Information supporting (b)(1) can be found on pages 157-58; (b)(2) can be found on pages 157-58; and (b)(3) is not applicable.

R-24-10

Require the installation, in all controlling locomotive cabs and cab car operating compartments, of crash and fire protected inward- and outward-facing audio and image recorders capable of providing recordings to verify that train crew actions are in accordance with rules and procedures that are essential to safety as well as train conditions. The devices should have a minimum 12-hour continuous recording capability with recordings that are easily accessible for review, with appropriate limitations on public release, for the investigation of accidents or for use by management in carrying out efficiency testing and systemwide performance monitoring programs. If necessary, obtain legislative authority to act on this recommendation.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.6, Locomotive Data Recorders. Information supporting (b)(1) can be found on pages 158-65; (b)(2) and (b)(3) are not applicable.

R-24-11

Require that railroads regularly review and use in-cab audio and image recordings (with appropriate limitations on public release), in conjunction with other performance data, to verify that train crew actions are in accordance with rules and procedures that are essential to safety. If necessary, obtain legislative authority to act on this recommendation.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.6, Locomotive Data Recorders. Information supporting (b)(1) can be found on pages 158-65; (b)(2) and (b)(3) are not applicable.

To the Pipeline and Hazardous Materials Safety Administration

I-24-1

Require that placards be able to survive fires and accidents and remain legible during such emergencies long enough to fulfill their functions as described in the Emergency Response Guidebook.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.3.3, Placard Legibility. Information supporting (b)(1) can be found on pages 121-22; (b)(2) and (b)(3) are not applicable.

R-24-12

Obtain the necessary legislative authority and accelerate the deadline for removing specification DOT-111 tank cars from flammable liquids service.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4.2, Non-Pressure Tank Cars. Information supporting (b)(1) can be found on pages 125-34; (b)(2) can be found on pages 133-34; and (b)(3) is not applicable.

R-24-13

Establish a tank car replacement schedule whereby non-pressure tank cars in any hazardous materials service must meet or exceed the safety standards of the DOT-117 specification; if necessary, obtain legislative authority to act on this recommendation.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4.2, Non-Pressure Tank Cars. Information supporting (b)(1) can be found on pages 125-34; (b)(2) and (b)(3) are not applicable.

R-24-14

Revise the definition of high-hazard flammable train to account for differences in survivability between tank car specifications and to include hazardous materials other than flammable liquids, such as combustible liquids and Division 2.1 flammable gases, that can contribute to cascading hazardous materials releases; if necessary, obtain legislative authority to act on this recommendation.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4.4, High-Hazard Flammable Trains. Information supporting (b)(1) can be found on pages 138-141; (b)(2) and (b)(3) are not applicable.

R-24-15

Distribute the Federal Railroad Administration's most current guidance on the vent and burn method to emergency response agencies by referencing it in the next edition of the Emergency Response Guidebook.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.5.4, Vent and Burn Criteria. Information supporting (b)(1) can be found on pages 157-58; (b)(2) can be found on pages 157-58; and (b)(3) is not applicable.

To the state of Ohio**R-24-16**

Amend your firefighter training statute and revise your volunteer firefighter certification standards to meet the NFPA 1010 standard for professional firefighters.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.3.1, Initial Deployment of Firefighters. Information supporting (b)(1) can be found on pages 113-15; (b)(2) and (b)(3) are not applicable.

To the Columbiana County Emergency Management Agency**R-24-17**

Adopt a policy to, upon receipt of a train consist, immediately provide it to the incident commander and all appropriate response agencies and departments.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.3.2, Communication and Consist Information. Information supporting (b)(1) can be found on pages 115-18; (b)(2) and (b)(3) are not applicable.

R-24-18

Update your Emergency Operations Plan, Hazardous Materials Response Plan, and Hazard Mitigation Plan, as appropriate, with lessons learned from the East Palestine derailment and fire, including, at a minimum, coordination among response agencies, communications, requests for and distribution of the train consist, staging and availability of equipment and other resources, and training for emergency responders.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.3.2, Communication and Consist Information. Information supporting (b)(1) can be found on pages 115–18; (b)(2) and (b)(3) are not applicable.

To the Association of American Railroads**R-24-19**

Develop a database of bearing failures and replacements and make it available to railroads, regulators, and investigators to help determine and address failure risk factors.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.2.5, Accident Bearing Failure Analysis. Information supporting (b)(1) can be found on pages 111–13; (b)(2) can be found on page 109 and (b)(3) is not applicable.

R-24-20

Revise the Manual of Standards and Recommended Practices, M-1002, Specifications for Tank Cars, to establish criteria and procedures for manufacturers of tank car service equipment to demonstrate compatibility of pressure relief devices and other Association of American Railroads-approved service equipment with intended loadings.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4.3.1, Tank Car and Fittings Certification. Information supporting (b)(1) can be found on pages 135–36; (b)(2) and (b)(3) are not applicable.

R-24-21

Revise the definition of key train in Circular OT-55 to designate as a key train any train containing tank cars transporting hazardous materials that do not meet the DOT-117 standard.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4.5, Key Trains. Information supporting (b)(1) can be found on page 141; (b)(2) and (b)(3) are not applicable.

To the National Volunteer Fire Council**R-24-22**

Identify barriers to adequate fire and emergency response training for volunteer firefighters, particularly for situations where hazardous materials are present, and publish actions states, municipalities, and the private sector can take to provide the flexibility necessary for volunteer firefighters to obtain training.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.3.1, Initial Deployment of Firefighters. Information supporting (b)(1) can be found on pages 113-15; (b)(2) and (b)(3) are not applicable.

To the International Association of Fire Chiefs, the International Association of Fire Fighters, and the National Volunteer Fire Council**R-24-23**

Advise your members of the circumstances of the East Palestine derailment and fire, identify fire departments whose personnel are not trained to the NFPA 1010 standard for professional firefighters, recommend that these departments adopt training that meets this standard, and inform them of funded training opportunities available through private, state, and federal programs.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.3.1, Initial Deployment of Firefighters. Information supporting (b)(1) can be found on pages 113-15; (b)(2) and (b)(3) are not applicable.

R-24-24

Advise your members of the circumstances surrounding the vent and burn at East Palestine, the importance of obtaining information from the shipper when considering a vent and burn, and the availability of federal guidance on when the vent and burn method may be appropriate.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.5.4, Vent and Burn Criteria. Information supporting (b)(1) can be found on pages 157-58; (b)(2) can be found on pages 157-58; and (b)(3) is not applicable.

To The Chlorine Institute**R-24-25**

Review and revise Pamphlet 171 to ensure that its safety messages about vinyl chloride monomer polymerization in tank cars are accurate and adequately support determining whether a rail accident poses a risk of polymerization.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.5.2, Quality of VCM Hazard Information. Information supporting (b)(1) can be found on pages 149-51; (b)(2) and (b)(3) are not applicable.

R-24-26

Review and revise your Chlorine Emergency Plan training and verification programs to ensure that Level 3 contractors possess or can obtain enough technical knowledge of vinyl chloride monomer (VCM) to accurately assess and respond to chemical hazards like polymerization during a VCM incident.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.5.2, Quality of VCM Hazard Information. Information supporting (b)(1) can be found on pages 149-51; (b)(2) and (b)(3) are not applicable.

To the American Chemistry Council and The Chlorine Institute:

R-24-27

Advise your members of the circumstances of the East Palestine derailment and fire and the need for shippers to ensure their expertise is communicated to and shared with the full incident command.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.5.3, Vent and Burn Communication and Justification. Information supporting (b)(1) can be found on pages 151-55; (b)(2) and (b)(3) are not applicable.

To Norfolk Southern Railway**R-24-28**

Review and revise your procedures to immediately provide emergency responders with an accurate copy of the train consist upon becoming aware of an accident.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.3.2, Communication and Consist Information. Information supporting (b)(1) can be found on pages 115-18; (b)(2) and (b)(3) are not applicable.

R-24-29

Update your submissions to the Pipeline and Hazardous Materials Safety Administration's Incident Database to accurately reflect the cause of package failures following the East Palestine derailment.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.5.1, Polymerization. Information supporting (b)(1) can be found on pages 142-49; (b)(2) and (b)(3) are not applicable.

R-24-30

Adopt policies to ensure that your emergency response contractors keep detailed records of information used to make decisions involving hazardous materials, and share this information with shippers, relevant chemical associations, and other entities that provide hazardous materials guidance.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.5.2, Quality of VCM Hazard Information. Information supporting (b)(1) can be found on pages 149-51; (b)(2) and (b)(3) are not applicable.

R-24-31

Develop a policy to ensure that expertise communicated to your on-scene representatives and contractors is shared with the full incident command.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.5.3, Vent and Burn Communication and Justification. Information supporting (b)(1) can be found on pages 151-56; (b)(2) and (b)(3) are not applicable.

To Oxy Vinyls, LP**R-24-32**

Update the safety data sheet for vinyl chloride monomer (VCM) to accurately reflect the potential risks of VCM and the hazards that increase such risks.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.5.2, Quality of VCM Hazard Information. Information supporting (b)(1) can be found on pages 149-51; (b)(2) and (b)(3) are not applicable.

R-24-33

Develop a policy to ensure that expertise on chemicals manufactured and offered for transportation by Oxy Vinyls is communicated to and shared with the full incident command during transportation accidents or incidents.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.5.3, Vent and Burn Communication and Justification. Information supporting (b)(1) can be found on pages 151-55; (b)(2) and (b)(3) are not applicable.

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