National Transportation Safety Board

Office of Railroad, Pipeline and Hazardous Materials

Washington, DC 20594

HMD22LR001

HAZARDOUS MATERIALS

Group Chair's Factual Report

July 20, 2022

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A. ACCIDENT

Location:	Oklaunion, Texas
Date:	January 8, 2022
Time:	9:49 AM CST 3:49 PM UTC
Train:	U JOENYF7-07A

B. HAZARDOUS MATERIALS GROUP

Group Chair	Marc Dougherty National Transportation Safety Board Washington, DC
Party Coordinator	Vernon Walker Tank Car Specialist – Federal Railroad Administration Washington, DC
Party Coordinator	Patrick Brady, CIH, CSP General Director, Hazardous Materials Safety – BNSF Fort Worth, Texas
Party Coordinator	Ron Lawler, Sr. Director Mechanical Services –Trinity Industries Leasing Co. Dallas, Texas

C. SUMMARY

For a summary of the accident, refer to the *Accident Summary Report* with this docket. Figure 1 shows the accident scene in Oklaunion, Texas (looking north).

Figure 1: Accident scene, Oklaunion, Texas, looking north, 1/8/2022, Courtesy: BNSF

D. FACTUAL INFORMATION

1.0 Hazardous Materials Shipper Information

Hereford Ethanol Partners L.P. (Hereford), Hereford, Texas, was incorporated in October 2020 after purchasing the plant from Green Plains Inc., with a capacity of about 100 million gallons of product per year at time of purchase. In July 2021, Hereford completed a series of upgrades to the facility, increasing the capacity to ship ethanol tank cars from 100 to 300 per month.

The plant houses a double loop train track allowing the plant the ability to continuously load ethanol unit trains, increasing efficiency without the need to uncouple and re-couple cars while loading.

Figure 2: Hereford Ethanol Partners LLC facility. Courtesy: Hereford Ethanol Partners LLC company website.

2.0 Hazardous Materials Information

The hazardous material transported on BNSF train U JOENYF7-07A was described on the consist as UN1987, Alcohols N.O.S (Ethanol and gasoline), Class 3, Packing Group II. The commodity is commonly known as denatured ethanol[1].

Denatured ethanol contains a substance(s) to make it unfit for human consumption. It is intended for use in motor fuels and as a fuel additive among other uses.

The shipper, Hereford Ethanol Partners L.P., provided the safety data sheet (SDS) for the ethanol dated March 3, 2021, which identified the product name as Denatured Ethanol, describing it as a highly flammable clear, colorless liquid. The following additional chemical and physical properties were listed:

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[1]*Denatured ethanol:* Fuel-grade ethanol is denatured with compounds such as natural gasoline to render it undrinkable in accordance with Alcohol and Tobacco Tax Trade Bureau regulations found in 27 *Code of Federal Regulations* (*CFR*) Part 2.

- **Physical State:** Liquid
- **Color:** colorless
- **Freezing Point: F:** -173.0˚F
- **Boiling Point: F:** 172.9˚F (@ 1 atm.)
- **Flash Point: F:** 55.0˚F (Ethanol; Closed Cup); -45.0˚F (Denaturant; est.)
- **Flammability (by %volume):** Upper Limit**:** 19.0% Lower Limit**:** 3.3%
- **Vapor Pressure (mmHg):** 44.6 mmHg @ 68˚F (Ethanol);
  6-15 mmHg @ 100˚F (Denaturant)
- **Vapor Density (Air = 1):** 1.59
- **Auto-Ignition Temperature: F:** 689.0˚F
- **Specific Gravity (H2O = 1):** 0.79
- **Percent Volatile:** 100%

Section 14 of the SDS states U.N. GHS Transport requirement for the proper shipping name to be identified as Alcohols N.O.S.

ERG Guide[2] 127 recommends an isolation distance of ½ mile in all directions if a rail car is involved in a fire. For large fires, the ERG advises to cool containers with flooding quantities of water until well after the fire is out. The use of alcohol-resistant foam is also recommended unless unable to control in the event of a massive fire, at which time, responders should withdraw and allow the fire to burn out.

3.0 Loading and Outage

On January 7, 2022, Hereford loaded and shipped the 96 tank cars that were placed in the derailed BNSF train U JOENYF7-07A. The loading operator conducted a pre-loading inspection of each tank car following a prescribed company checklist. After the pre-loading inspection, the operator entered the loading information into a metered loading system with predetermined amount of product to be loaded in each car after visual heel inspection is completed.[3]

Tank car outage and filling limit requirements are prescribed in 49 CFR 173.24b(a). The requirement applicable for flammable liquids transportation is that the outage must be at least 1 percent of the total capacity of the tank car at a reference temperature of 110℉ for a tank car having a thermal protection system.

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[2] United States Department of Transportation, *2020 Emergency Response Guidebook*, Guide 127, Flammable Liquids (Water-Immiscible), p. 191.

[3] Heels are the amount of residue remaining in the tank car after it has been unloaded.

The bills of lading provided by the shipper identified the origin of the shipment as Hereford Ethanol Partners LLC, 4300 County Road 8, Hereford, Texas 79045. The consignee and destination terminal were listed as Lincoln Oil (c/o Musket Terminal) 1 Main Street, Fort Worth, Texas 76106. Both the BOL and train consist described the product as UN1987, Alcohols N.O.S (Ethanol and gasoline), 3, PGII with the provided quantity loaded to each tank car as indicated in Table 1.

Table 1. Quantity Loaded with Outage

Line #	Car Mark	Car Number	Tank Capacity (gal)	Loaded Volume (gal)	Outage (gal)	Outage (%)
36	TILX	731777	30430	28999	1431	4.8
37	TILX	731779	30460	28996	1464	4.9
38	TILX	731692	30320	28999	1321	4.5
39	TILX	731698	30380	28998	1382	4.7
40	TILX	731775	30380	29000	1380	4.6
41	TILX	731680	30300	29000	1300	4.4
42	TILX	731721	30350	28997	1353	4.6
43	TILX	731782	30340	28999	1341	4.5
44	CRDX	300110	30300	28999	1301	4.4
45	CRDX	300070	30220	29001	1219	4
46	CRDX	300133	30240	29000	1240	4.2
47	TILX	731379	30390	28998	1392	4.7
48	TILX	731462	30440	28999	1441	4.8
49	TILX	731464	30420	29000	1420	4.8
50	TILX	731426	30430	29001	1429	4.8
51	TILX	731748	30360	29001	1359	4.6
52	TILX	731754	30380	28997	1383	4.7
53	TILX	731717	30360	28998	1362	4.6
54	TILX	731739	30340	29000	1340	4.5
55	TILX	731726	30370	28999	1371	4.6
56	CRDX	300077	30280	29001	1279	4.3
57	CRDX	300073	30240	28997	1243	4.2
58	CRDX	300059	30180	28999	1181	4
59	TILX	731429	30370	29000	1370	4.6
60	CRDX	300056	30210	29000	1210	4.1
61	CRDX	300019	30240	29000	1240	4.2
62	CRDX	300093	30220	28997	1223	4.1
63	TILX	731751	30370	28999	1371	4.6
64	TILX	731741	30400	28998	1402	4.7
65	TILX	731758	30360	29027	1333	4.5
66	TILX	731762	30360	29000	1360	4.6

Attached to each bill of lading was a certificate of analysis for the denatured ethanol, conducted by a third-party laboratory (Murex) indicating the following parameters in Table 2:

Table 2. Certificate of Analysis

Ethanol; vol%	92.1 min
Methanol; vol%	0.5 max
Solvent Washed Gum; mg/100ml	5.0 max
Water; vol%	1.0 max
Chloride; mg/L	8 max
Copper; mg/L	0.1 max
Acidity (as acetic acid); wt%	0.007 max
pH	6.5-9.0
Sulfur, ppm	10 max
Total Sulfate, ppm	4 max
Visual Appearance	Clear and Bright
Benzene; vol%	0.06 max
Olefins; vol%	.5 max
Denaturant Content; vol%	1.96 to 2.49

After the tank cars were loaded, the operator conducted a final inspection of all appurtenances to include manways, liquid valves, bottom outlet valves and vacuum relief devices, as required by 49 CFR 173.31 - Use of tank cars.

The loader found no exceptions with the pre- and post-load condition of the tank cars and released the train to the railroad on January 8, 2022.

Prior to accepting tank cars loaded with hazardous materials, BNSF is required to complete a safety and security inspection of each tank car, at ground level, for prescribed items per 49 CFR 174.9, Safety and security inspection and acceptance. Once the ground level inspection is completed and all items verified in accordance with the regulations, the carrier may transport the cars.

The railroad found no exceptions with condition of the tank cars prior to transportation.

On February 24, 2022, following the derailment, the Federal Railroad Administration (FRA) visited the shipper's Hereford, TX facility to review railcar loading and securement procedures for fuel ethanol. FRA inspectors discussed the Renewable Fuels Association guides for rail transport of ethanol, manways, preventing non-accidental releases (NARs), and AAR Pamphlet 34. Observations made by FRA during the site visit included the following:

1. Unacceptable pre-inspection of tank cars prior to loading.
2. Missing critical elements of the pre-/post-loading checklist.
3. Improper manway securement torque values.
4. Omission of visual heel verification/ determination in tank cars prior to loading.
5. No procedures or practices for cleaning and lubrication of manway eyebolt threads.

The observations were not identified as defects or violations.

4.0 <u>DOT 117J100W1 Tank Car Design and Derailment Damage</u>

Title 49 of the Code of Federal Regulations (CFR) Part 179 outlines the following specification requirements for DOT-117 tank cars: (1) Subpart B of Part 179 - general design requirements; (2) Subpart D - specifications for non-pressure tank car tanks. Additional tank car industry standards incorporated in the HMR by reference are: The Association of American Railroads (AAR) Manual of Standards and Recommended Practices, Section C-Part III, Specifications for Tank Cars, Specification M-1002.

In accordance with federal regulations for the operation of high-hazard flammable trains at 49 CFR 174.310, after October 1, 2015, new tank cars manufactured for use in a HHFT must be constructed to the specification DOT-117, or 117P performance standard as specified in Subpart D-Specifications for Non-Pressure Tank Car Tanks, or an authorized tank specification as specified in Part 173, subpart F. Among the DOT-117 specification requirements are:

- 9/16-inch normalized TC-128 steel minimum for heads and shells
- Full height ½ inch thick head shield
- Thermal protection system
- Minimum 11-gauge jacket
- Top fittings protection
- Enhanced bottom outlet handle design to prevent unintended actuation during a train accident
- 286,000 lbs. GRL authorized

4.1 Thermal Protection Systems

49 CFR 179.202-6 outlines specific thermal protection requirements for DOT117J specification tank cars. The performance standard for thermal protection prescribed in 49 CFR 179.18 indicates that no release of any lading within the tank car (with exception of the pressure release device) should occur when subjected to the following:

1. A pool fire for 100 minutes; and
2. A torch fire for 30 minutes.

Federal regulations at 49 CFR 179.18(b) also require verification of thermal analysis regarding the fire effects on the entire surface of the tank car including fire effects on and heat flux through tank discontinuities, metal jackets, insulation, thermal protection, underframe, and protective housings. The regulation specifies that the procedures outlined in Federal Railroad Administration (FRA) publication "Temperatures, Pressures, and Liquids Levels of Tank Cars Engulfed in Fires" is acceptable for analyzing the fire effects on the entire surface of the tank car.[4] The current fourth-generation Analysis of Fire Effects on Tank Cars (AFFTAC) software is the tool tank car manufacturers use for evaluating thermal protection system performance.[5] When the analysis shows the thermal resistance of the tank car does not conform to the pool fire and torch fire performance standard, the thermal resistance must be increased by using an approved system listed by PHMSA or by testing the thermal protection system using simulated pool and torch fire test procedures described in Appendix B of Part 179.

The regulation does not specifically mention sustainability of gasket material within the discontinuities, however, pre-approved thermal protection systems that comply with the requirements are published by PHMSA.[6] If a thermal protection system from the pre-approved list is installed, test verification is no longer necessary.

The tank car builder, Trinity Tank Car, Inc. (Trinity), used a thermal protection system that consisted of ½-inch thick ceramic blanket. An independent testing laboratory conducted a fire resistance evaluation of material samples in accordance

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[4] *Temperatures, Pressures, and Liquid Levels of Tank Cars Engulfed in Fires*, DOT/FRA/OR&D-84/08.11, (Washington DC: Federal Railroad Administration, 1984).

[5] The Analysis of Fire Effects on Tank Cars (AFFTAC) is a computer model that simulates the effects of fire on rail tank-cars. It is used by the U.S. DOT, Transport Canada, and tank-car manufacturers for evaluating and qualifying thermal protection systems for rail tank-cars. *AFFTAC 4.00, RSI-AAR Railroad Tank Car Safety Research & Test Project.* (Washington DC: Railway Supply Institute, 2016).

[6] See https://www.phmsa.dot.gov/standards-rulemaking/hazmat/tank-car-thermal-protection-system-list,

with the pool and torch fire simulations of Appendix B and reported that the ceramic fiber met the conditions of the standard.

Additionally, on March 4, 2022, Trinity completed post-derailment AFFTAC simulations for the thermal protection system and DOT-117J tank car configuration. The thermal protection system characteristic data inputted into the AFFTAC program for analysis considered tank discontinuities to be insulated. However, the AFFTAC simulations did not perform a thermal stress analysis on the discontinuities themselves. Trinity's simulations found the tank car and thermal protection system combinations surpassed the 100-minute pool fire survival and 30-minute torch fire survival requirements.

No on-scene observations or evidence were recorded by first responders following the derailment to determine the thermal protection system survival times before releases occurred. About 353,000 gallons of ethanol released from 18 tank cars that sustained no mechanical breaching damage, but experienced thermal damage to tank discontinuities and venting of pressure relief devices.

Temperature readings were recorded during the pool fire at unspecified dates/times by BNSF detailing the following:

- West end of the derailment – tank cars upright on track (90-200 F)
- First rail car on fire from upright tank cars (700-800 F)
- Middle of derailment tank car with top fittings protective housing sheared off (800 – 1040 F)
- East end of derailment – cars overturned but not on fire (ambient temperature)

4.2 Gasket Materials

Trinity design and manufacturing specification drawings for the derailed DOT-117 tank cars prescribed elastomeric (Buna-N) gaskets to be installed in the manway. Elastomeric gaskets are widely used on general service tank cars for a range of commodities. The shipper provided the specifications for the elastomeric gaskets used on the derailed tank cars which show an operating temperature of -40 ˚F to +210 ˚F. According to the manufacturer's specifications, elastomeric gaskets are prone to mechanical damage, such as splices, due to over-torquing, overuse, and misalignment.

Additional Trinity specifications call for Tealon (TF1570E) gaskets to be installed on all other fittings. Tealon 1570E is a restructured polytetrafluoroethylene (rPTFE) material manufactured for various chemicals and products. Maximum service temperature of the TF1570E gasket material is 500 ˚F.

Trinity maintenance instructions pertaining to replacement of manway gaskets provides steps and requirements for replacing the gasket in hinged and bolted manway covers on company-owned and managed tank cars. Instructions detail the shipper's responsibility for proper gasket selection, inspection for defects, torque pattern and values, among other items.

NTSB investigators found the elastomeric manway gaskets on 26 of the derailed cars were thermally destroyed (see Appendix A for further details). Figure 3 shows a gasket removed from a minimally damaged tank car (TILX 731757, #72) involved in the derailment (identified as Buna-N), which was submitted to the NTSB laboratory for examination (Control # HMD22LR001-HAZ-004). Upon removal from the manway, investigators observed a cut in the gasket surface. Figure 4 pictures a thermally damaged elastomeric gasket that had been reduced to carbon removed from TILX 731758, #65) also submitted to the NTSB laboratory for examination (Control #HMD22LR001-HAZ-006).

(See the NTSB Materials Laboratory Thermal Testing of Polymeric Railcar Gasket, Review Report No. 022-052F in this docket for further details).

Figure 3. Nitrile rubber Buna-N manway gasket removed from TILX 731757 (#72) for lab analysis (Control# HMD22LR001-HAZ-004). January 28, 2022.

Figure 4. Thermally damaged manway elastomeric Buna-N gasket reduced to carbon, TILX 731758 (#65). Removed for lab analysis (Control#HMD22LR001-HAZ-006). January 28, 2022.

4.3 <u>Bottom Outlet Valve Skid Protection and Operating Assembly</u>

AAR MSRP, M-1002, Appendix E, 9.1.1 (Appendix E) and 49 CFR 173.31(b)(5), Bottom-discontinuity protection requirements, requires new, non-pressure stub sill tank cars to have an approved method of protection against impact for bottom discontinuities that project beyond the shell envelope. This includes bottom outlets, washouts, blind flanges, or sumps. Exceptions to this rule are tank cars transporting material which meets the definition of elevated temperature or molten sulfur.

For bottom discontinuities, a protective device must be designed as follows among others:

1. A load, normal to the slope of the protective device, whose vertical component equals the rail load minus the weight (mass) of the trucks.
2. The above load must be considered as concentrated on any transverse line on the protective device.
3. The stresses in the tank shell, protective device, and their connections must not exceed the minimum tensile strength of the material. The stresses in the webs of the protective device must not exceed the critical buckling stress.

Following the June 19, 2009, derailment of a Canadian National Railway freight train in Cherry Valley, Illinois, the NTSB found that previous general service tank car bottom outlet valve operating mechanism designs did not ensure that the BOV would remain closed if the handle failed to break free in an accident[7]. In this and subsequent investigations, the NTSB found instances of bottom outlet valve handles being bent or pulled away from their securement brackets during derailments, causing the ball valves to unseat and release lading[8]. In these cases, the NTSB determined that inadvertent actuation of the valve handle to the open position could occur after the BOV nozzle was sheared off, with no way of stopping product loss through the damaged valve.

As a result of the Cherry Valley, Illinois accident, the NTSB was prompted to issue Safety Recommendation R-12-006 to the PHMSA:

> 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. (Closed – Acceptable Action)

On July 12, 2016, the NTSB classified Safety Recommendation R-12-006 as closed with acceptable action following the issuance of PHMSA final rule HM-251 that requires bottom outlet valve protection for the DOT-117 tank car, including performance and retrofit standards in sections 179.202-8, 179.202-12(e), and 179.202-

[7] National Transportation Safety Board, Derailment of CN Freight Train U70691-18 With Subsequent Hazardous Materials Release and Fire, Cherry Valley, Illinois, June 19, 2009, RAR-12/01 (Washington DC: National Transportation Safety Board, 2012)

13(g), specifically that all bottom outlet handles must either be removed or designed to prevent unintended actuation during derailment scenarios.

4.3.1 BOV Skid Protection

The Trinity skid protection on the derailed cars consists of 1/2-inch-thick metal plates married to form a protective housing around the bottom outlet valve assembly. The bottom outlet valve body is recessed into the tank saddle and skid while the outlet nozzle and secondary valve extend beyond the plane of the bottom skid plate. The design intends for both to shear away in the event of a derailment or contact damage. This skid is intended to protect the valve body by preventing unintended release if the nozzle and secondary valve are sheared away.

Three structural failures of the BOV center skid were observed following this derailment. The skid failures accompanied a mechanical breach to the BOVs and loss of product, to include shearing of the full BOV assembly and ball valve from the saddle (Figures 5 – 8).

AAR Tank Car Committee task force T10.31 is currently working to develop new standards for skid protection structures, but the AAR has not published a final standard at the time of this report.

Figure 5. Center skid structure collapsed, shearing full BOV assembly and ball valve, TILX 731739. January 27, 2022.

Figure 6. BOV nozzle sheared off. Valve body remained intact and closed at skid shear plane. TILX 731782. January 11, 2022. Courtesy Trinity Industries Leasing, Inc.

Figure 7. Center skid structure collapse with nozzle assembly sheared as seen hanging by the safety chain. Ball valve partially opened and BOV handle disengaged. CRDX 300056. January 26, 2022. Courtesy Trinity Industries Leasing, Inc.

Figure 8. Skid structure missing/sheared away along with full BOV assembly and ball valve. Angular flap of center skid remains. TILX 731680. January 27, 2021.

4.3.2 BOV Disengaging Handle

49 CFR 179.203-8 and Appendix E requires (if equipped) the bottom outlet assembly to be designed with a protection safety system(s) to prevent unintended actuation during train accident scenarios. Tank cars built new on or after July 1, 2015, equipped with external bottom outlet valves to meet the following among other items:

1. Handle that is disengaged from the valve when in the closed position and located outside the skid:
   a. When in the closed position, must be equipped with a means to prevent unintended engagement with the valve.

The BOV handle is a disengaging device designed to be used with its associated bottom outlet valve. Various BOVs and disengaging handle combinations exist and must adhere to federal regulation 49 CFR 179.103(b)(3) which states the valve operating mechanism must be provided with a suitable locking arrangement; this ensures positive closure during transit. 49 CFR 179.200(a)(4) further details that the construction must ensure against unseating of the valve due to stresses or shocks incident to transportation.

After loading/unloading, the BOV handle is disengaged, stowed, and/or locked to prevent actuation of the BOV and loss of product by inadvertent operation or damage to the handle).

The BOV handle adapter (Figure 9) is designed for the BOV handle to be disconnected and disengaged from the valve during transportation, preventing unintended actuation of the BOV. The BOV adapter is designed to break off at the shear grove, preventing rotation and actuation of the BOV with subsequent product loss.

Follow-up inspection of the derailed tank cars found at least three instances of damaged BOV adapters to shear at the groove, but rather bent the adapters and/or sheared above the groove, toward the slotted end (Figures 10-12).

Six shear plane surface-to-BOV adapter shear groove alignment issues were observed following the derailment. The shear groove of the BOV adapter in those cases was observed below the shear plane surface. One undamaged BOV adapter removed from (TILX 731762, #66) was submitted to the NTSB laboratory for examination (Control #HMD22LR001-HAZ-003) (See the NTSB Materials Laboratory factual report in this docket for further details).

Figure 9. Salco BOV stem Adapter. (Courtesy Salco Products, Inc.)

Figure 10. BOV stem adapter with witness mark/ contact damage without breakage at shear groove, CRDX 300133. January 11, 2022. Courtesy Trinity Industries Leasing, Inc.

Figure 11. BOV skid protection structure, shallow dent A-end side (right side in photo). BOV handle adapter not sheared and BOV ball valve seen partially open, CRDX 300073. January 27, 2022

Figure 12. BOV stem adapter with top surface torsional fracture. Slotted end was severed and missing, CRDX 300073. January 27, 2022

4.4 Top Fittings Damage and Pressure Relief Device (PRD) Actuation

NTSB investigators found two tank cars with top fittings mechanical damage and breaches: (Figure 13) shows TILX 731462 with all top fittings and valves sheared off, and Figures 14 and 15 show damage to the protective housing of CRDX 300133 and one 3-inch valve partially sheared from the flange.

In addition, 20 pressure relief devices (PRDs) activated following the derailment with subsequent pool fire. PRDs are designed, under fire conditions and in conjunction with the thermal protection system, to limit the pressure buildup in tank cars. The PRDs involved in the derailment were spring-actuated, self-reclosing devices intended to open at a prescribed start-to-discharge pressure and remain open until the pressure falls below the set minimum.

Figure 13. Missing top fittings protective housing with all top fittings sheared from flange. TILX 731462. Courtesy Trinity Industries Leasing, Inc., January 9, 2022.

Figure 14. Mechanically damaged top fittings protective housing. CRDX 300133. Courtesy Federal Railroad Administration, January 11, 2022.

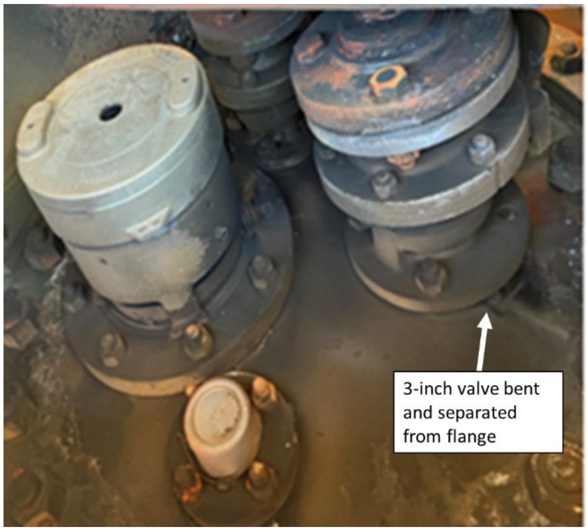

Figure 15. Three-inch valve sheared from flange below damage to protective housing. CRDX 300133. Courtesy Federal Railroad Administration, January 11, 2022.

4.5 Underframe

The derailed Trinity-owned tank cars were all equipped with a Type 24 (TRN024) stub sill design. Tank car stub sills are welded to reinforcement pads (re-pads) rather than directly to the tank. In the event of a derailment, the stub sill is designed to break away from the re-pad during excessive stub sill loading without breaching the tank head.

Figure 16 shows consist number 63, TILX 731751, with a tank shell breach and separation of the stub sill attachment re-pad. The tank head sustained three consecutive localized impacts as indicated in Figure 17.

A-end stub sill head pad section with tank breach at the fractured A-3 stub sill "window weld" removed from the tank car and sent to the NTSB laboratory for examination (Control # HMD22LR-HAZ-002) (Figure 18). Figure 19 drawing of the head brace assembly shows welds in Section G-G, where the facture occurred.

(See the NTSB Materials Laboratory factual report in this docket for further details).

Figure 16. Tank shell breach showing separated head brace and fractured re-pad. TILX731751. January 27, 2022.

Figure 17. A-end head identifying three localized impacts, TILX 731751. January 27, 2022.

Figure 18. A-end stub sill/head pad/tank section removed for NTSB laboratory examination. TILX 731751. January 28, 2022.

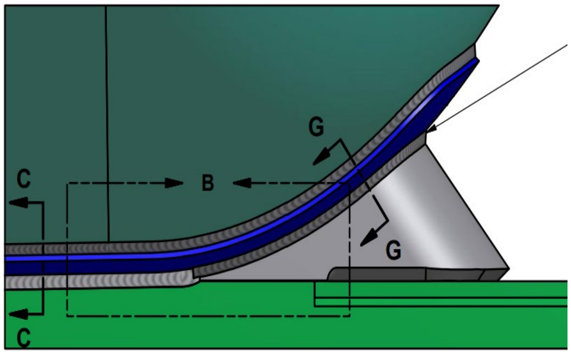

Figure 19. Drawing of head brace depicting re-pad and welds at location of tank fracture. (Courtesy, Trinity Industries Leasing, Inc.)

4.6 Weld Calculations and Reinforcing Pads

Tank cars are designed with the intention that components attached to these reinforcement pads will separate (shear or tear away) in derailment scenarios without fracturing the tank and compromising lading retention. Title 49 CFR 179.200-19 (b) with reference to proposed rulemaking HM-90 titled; "Specifications for Tank Cars" published in August 1971, outlines the requirement for reinforcing pads between external brackets and shells if welds exceed 6 lineal inches of ½-inch fillet weld or equivalent per bracket or bracket leg, in addition to other criteria. The bracket to reinforcing pad welding criteria is based on an "85 percent rule", annotated in the regulation. The rule describes that the ultimate shear strength of the bracket to reinforcing pad weld must not exceed 85 percent of the ultimate shear strength of the reinforcing pad to tank weld. The origin and data analysis on this rule is unknown and current tank car build/welding criteria is still based on the language in this rulemaking.

Design calculations for the Trinity-type 24 stub sill welds indicated the stub sill to reinforcing pad welds were supposed to have a shear strength of 82.6% of the shear strength of the pad-to-tank welds.

4.7 Eduction Pipe Design and Securement

The eduction pipe installed on the derailed tank cars was designed by Trinity and made of non-flexible, non-breakaway, 3-inch Schedule 40 stainless steel pipe. The pipe has a 45-degree angle offset, installed vertically from the top liquid line valve to the bottom outlet valve sump area, connected by a guide assembly. The pipe is welded with a ¼-inch fillet weld at both legs.

Follow up inspection of the derailed tank cars revealed four eduction pipes displaced along with damage to the BOV ball valve as seen in figures 20 and 22. Investigators found broken welds at the guide assembly that were designed to prevent the eduction pipe from shifting. Figure 21 shows proper placement of eduction pipe in the guide assembly.

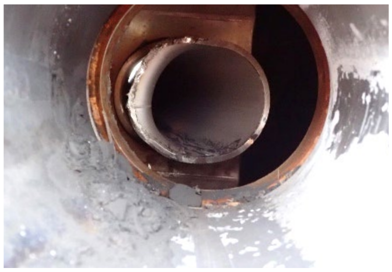

Figure 20. Flared (impact damaged) eduction pipe bottom as seen through the open bottom outlet ball valve, TILX 731748. January 27, 2022.

Figure 21. Eduction pipe placement in guide assembly over BOV, TILX 731739. January 27, 2022.

Figure 22. Displaced eduction pipe and flange as seen through BOV hole (Investigators removed the bottom outlet valve from the flange), TILX 731762. January 27, 2022.

5.0 Emergency Response and Site Remediation

5.1 Emergency Response

BNSF RR led and directed the emergency response efforts, coordinating with 14 responding agencies, including Sheppard Air Force Base (SAFB). SAFB fire department (40 miles away) was equipped for the large-scale response and staged a 700-gallon alcohol-resistant foam trailer. Incident command and the SAFB Fire Chief made a determination that foam would not be effective on the pool fire, by the time they had arrived on scene. The consensus among responders and BNSF RR was to allow the fire to burn out while cooling with water, as necessary. The derailment and subsequent pool fire were in a rural area surrounded by farmland, with one adjacent (vacant) structure. Responders determined that there was no imminent danger to the public, while allowing the pooled ethanol to burn off. About 100 acres of adjacent pasture were burned and an unoccupied ranch structure was destroyed in the fire.

Sheppard Air Force Base's post-derailment report outlined the following timeline showing the cascading effect of the pool fire following the derailment:

1030L – Initial report of five tank cars burning.

1145L – Fire Chief reported seven tank cars involved and (vacant) house engulfed.

1415L – 4000-gallon water tender deployed – 25 tank cars burning.

1730L – Relief crew responded – fire burned for several hours during fire suppression operations.

5.2 Site Remediation

Recovery and soil remediation following the Oklaunion derailment is ongoing. Soil screening sample collection was completed in the days following the derailment by a BNSF contractor. The derailment footprint was about 550 linear feet of track with soil samples collected at 100-ft intervals on both sides of the mainline track. Impacts were observed approximately six feet below ground surface in some locations. Soil samples were tested for ethanol and benzene, toluene, ethylbenzene, and xylenes (BTEX) analyses using EPA Method 8260[9] to determine proper disposal options. The contractor recovered about 2,500 gallons of liquids from the fire, which was stored in a frac tank, pending disposal.

Impacted soil delineation will continue, and BNSF is evaluating remedial options. A final report will be completed following all environmental remediation activities. The report will include site description, off-site activities, analytical data summary, laboratory reports, photographs, disposal/recycling information, among others.

6.0 Tank Car Breaches and Product Loss

Of the 37 derailed tank cars, 18 (49%) only released product by thermal damage to the manway, top and bottom fittings gaskets, valve seats, and O-rings, releasing 58.7% (353,475 gallons)[10] of the total 601,819 gallons lost. Three (3) cars (13.5%) only released material after sustaining mechanical damage to the fittings and manways, releasing about 11% (68,459 gallons) of product.[11]

The remainder of the 30% (179,885 gallons) of lost product was through mechanical damage/breaches to 7 tank car shells/heads as outlined in Tables 4, 5, and 6.

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[9] U.S. EPA. 2006. "Method 8260D (SW-846): Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)," Revision 3. Washington, DC. U.S. EPA. 2006 "Method 8260D (SW-846)

[10] Some volume of ethanol was released through normal functioning of PRDs but unable to differentiate or quantify volume lost by PRD versus manway thermal damage.

[11] The primary release modes are listed here. Some tank cars exhibited multiple breaching mechanisms. Mechanical damage is given precedence because this mode of breaching occurs before thermal damages.

Table 4. Oklaunion TX service equipment damage

Derailment	Speed (MPH)	Spec	Lading	Derailed	No. Cars Manway Thermal Breach	No. of Cars Manway Mech. Breach	No. Cars Valves Mech. Breach	Fire
Oklaunion, TX	50	117J	Ethanol	37*	20	3	4	Yes

* 6 tank cars were re-railed and removed from the derailment scene

Table 5. Release amounts (gallons) by type of damage

Damage Type	Release Amount (gallons)
Mechanical Damage Head and Shell	179,885
Mechanical Damage Manway and Fittings	68,459
Thermal Damage Manway and Fittings	353,475
Total	601,819

BNSF determined the amount of released denatured ethanol based on the measurement of recovered material from the derailed tank cars. The breakdown per tank car, with total amount of denatured ethanol released in this accident, was 601,819 gallons (Table 6). The released ethanol was either absorbed in surrounding soils and debris or consumed in the post-accident fire.

Table 6. Ethanol Release Figures

Car Sequence	Init	Number	Load Volume (Gal)	Ethanol Transferred (Gal)	Calculated Loss (Gal)	Primary Breaching Damage
39	TILX	731698	28,940	14,417	14,504	Thermal - Fittings
40	TILX	731775	28,936	14,417	21,281	Thermal - Fittings
41	TILX	731680	28,931	0	28,931	Mechanical -Fittings
42	TILX	731721	28,934	28,834	17,657	Thermal - Fittings
43	TILX	731782	28,915	3,604	26,239	Thermal - Fittings
44	CRDX	300110	28,939	7,208	27,407	Thermal - Fittings
45	CRDX	300070	28,940	9,515	26,375	Thermal - Fittings
46	CRDX	300133	28,961	28,834	28,961	Mechanical -Fittings
47	TILX	731379	28,932	14,417	23,953	Thermal - Fittings
48	TILX	731462	28,914	23,834	10,567	Mechanical -Fittings
49	TILX	731464	28,935	0	28,935	Mechanical - Shell
50	TILX	731426	28,955	28,834	15,465	Mechanical – Shell
51	TILX	731748	28,949	23834	19,297	Thermal - Fittings
52	TILX	731754	28,934	3,604	26,258	Mechanical - Shell
53	TILX	731717	28,916	23,834	21,758	Thermal - Fittings
54	TILX	731739	28,935	0	28,935	Mechanical - Shell
55	TILX	731726	28,938	19,319	19,447	Thermal - Fittings
56	CRDX	300077	28,930	0	28,930	Mechanical - Shell
57	CRDX	300073	28,937	0	28,937	Thermal - Fittings
58	CRDX	300059	28,915	9,515	18,196	Thermal - Fittings
59	TILX	731429	28,935	28,834	6,345	Thermal - Fittings
60	CRDX	300056	28,956	7,208	16,596	Thermal - Fittings
61	CRDX	300019	28,943	14,417	17,948	Thermal - Fittings
62	CRDX	300093	28,931	23,834	3,389	Thermal - Fittings
63	TILX	731751	28,917	2,881	28,917	Mechanical - Shell
64	TILX	731741	28,933	7,208	25,695	Thermal - Fittings
65	TILX	731758	29,027	14,417	18,451	Thermal - Fittings
66	TILX	731762	28,932	7,208	22,445	Mechanical - Shell
Lines 39 – 66 Totals			**810,260**	**208,441**	**(601,819)**	

7.0 Follow-up Examination of Derailed Tank Cars

On January 27-29, 2022, NTSB investigators and parties to the investigation (Hazardous Materials Group) inspected the derailed tank car wreckage, that had been staged in a field adjacent to the accident scene. See Appendix A for additional damage assessment details

E. LIST OF ATTACHMENTS

ATTACHMENT 1 – BNSF TRAIN CONSIST, OKLAUNION, TEXAS, JANUARY 8, 2022.

ATTACHMENT 2 – HEREFORD ETHANOL PARTNERS LLC., LOADING CHECKLIST, JANUARY 6, 2022

ATTACHMENT 3 – HEREFORD ETHANOL PARTNERS LLC., BILLS OF LADING, JANUARY 7, 2022

ATTACHMENT 4 – BNSF TEMPERATURE READINGS

ATTACHMENT 5 – SHEPPARD AIR FORCE BASE AFTER ACTION REPORT, JANUARY 12, 2022

ATTACHMENT 6 – BNSF DERAILED EQUIPMENT FLAMMABLE LIQUIDS LOSS AND RECOVERY,

ATTACHMENT 7 – FEDERAL RAILROAD ADMINSTRATION TANK CAR DAMAGE ASSESSMENT FORMS

Submitted by:

Marc Dougherty
Hazardous Material Group Chair

APPENDIX A

Tables A-1 through A-20 summarize field observations collected for the derailed tank cars.

Key to abbreviations used in this Appendix

B-end: the end of the car with the handbrake wheel
A-end: the end of the car opposite the B-end
A-L: A-end, left side
A-R: A-end, right side
B-L: B-end, left side
B-R: B-end, right side
BOV: bottom outlet valve
PRD: pressure relief device
Top: 4-feet to the right and left of the top longitudinal centerline
Bottom: 4-feet to the right and left of the bottom longitudinal centerline

All observations and orientations provided are from the perspective of facing the B-end of the tank car.

To provide an understanding of tank car damage context, Figure 21 shows the breached tank cars in-situ and provide orientation marks for the original train configuration and leading tank ends.

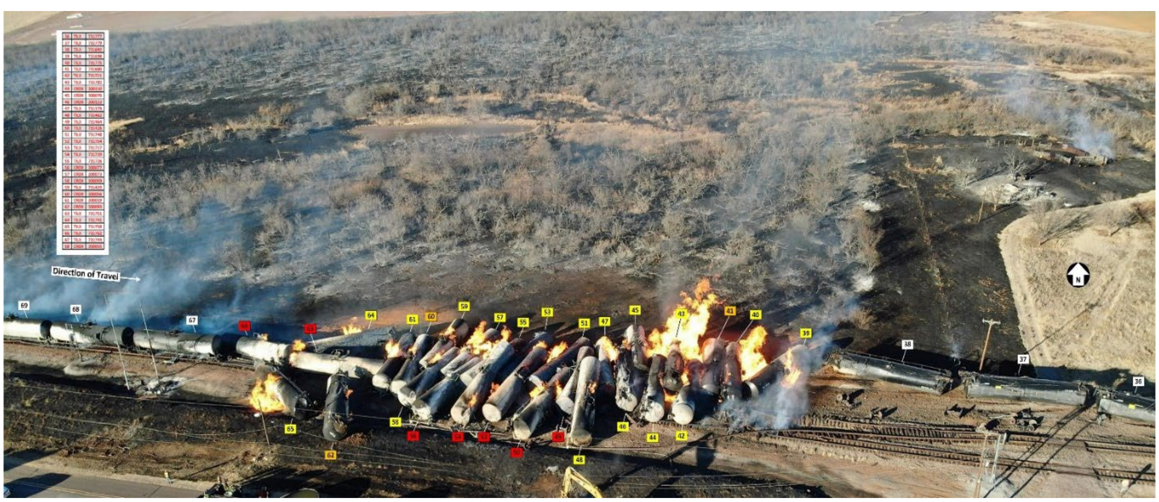


Figure 21. Breached tank cars in-situ with orientation marks.

Table A-1: Tank Car TILX 731680

Consist order	**41**
Orientation in the consist	A
Heads	No damage.
Shell	Significant jacket tearing, wrinkling, and thermal damage. No shell breach.
Bottom outlet valve	Most of the BOV skid protection structure was missing with flap of flattened structure hanging. BOV saddle missing, and bolts sheared/ smeared toward the B-L side. A dent in the BOV flange indicates impact from the A-R direction.
Top fittings, PRD and Manway	No thermal damage to manway or top fittings.
Stub sills	No recorded damage.
Breach/ Loss of Product	Mechanical / Full loss of product (28, 931 gallons)

1(a) Missing bottom outlet valve and saddle, and sheared skid protection structure.

1(b) Full BOV assembly sheared away from the saddle.

1(c) Protective housing cover torn off and crushed.

Table A-2: Tank Car TILX 731721

Consist order	**42**
Orientation in the consist	A
Heads	No damage.
Shell	Jacket thermal damage with several dents and tears (Figure 2a)
Bottom outlet valve	BOV skid protection structure collapsed in the center. BOV saddle missing, and bolts sheared/ smeared toward the B-L side. A dent in the BOV flange indicates impact from the A-R direction (Figure 2b). BOV stem bent.
Top fittings, PRD and Manway	Thermal damage to manway and top fittings (Figure 2c). 2 manway eyebolts bent. Protective housing damaged.
Stub sills	A-end draft sill torn
Breach/ Loss of Product	Thermal / 17,657 gallons

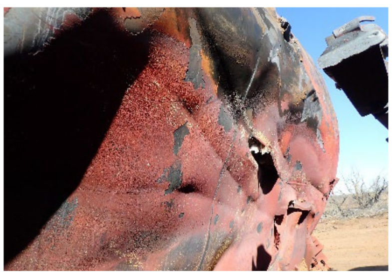
2(a) Heavy thermal and mechanical jacket damage. Missing bottom outlet valve and saddle, and collapsed skid protection structure.

2(b) Bottom outlet valve sheared off with ball intact.

2(c) Thermal damage to manway with visible carbon on lid.

Table A-2.1: Tank Car CRDX 300110

Consist order	**44**
Orientation in the consist	A
Heads	No breach observed
Shell	Significant jacket tearing, wrinkling, and thermal damage (Figure 2.1a) .
Bottom outlet valve	Valve intact. Handle bent
Top fittings, PRD and Manway	PRD Activated.
Stub sills	Stub sill scorched (red). A-end stub sill bent upward 45 degrees to the right. Head brace-to-stub sill weld fractured
Breach/ Loss of Product	Thermal / 27,407 gallons
Additional Notes	Aerial image indicated pool fire at the A-end, evidenced by red scorched jacket. Flame impingement where adjacent car (line 43) came to rest on its multi-housing



2.1(a) Buckled A-end stub sill. Head brace and pad.

2.1(b) A-end head brace and pad with fractured head brace-to-stub sill weld.

2.1(c) Adjacent car (43) TILX731782 resting on left side of top fittings protective housing of (44) CRDX300110, with flame impingement. Pool fire at A-end of the car.

Table A-3: Tank Car CRDX 300070

Consist order	**45**
Orientation in the consist	A
Heads	No damage.
Shell	Jacket around the B-L side of the manway was scorched.
Bottom outlet valve	No damage.
Top fittings, PRD and Manway	Thermal damage to the top fittings and interior surface of the protective housing.
Stub sills	A-end stub sill twisted about 5 degrees toward the right.
Breach/ Loss of Product	Thermal / 26,375 gallons

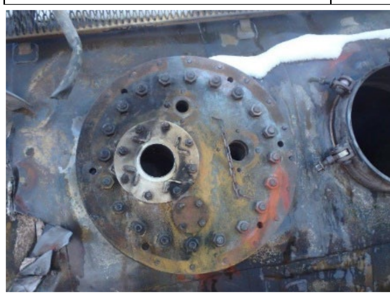
3(a) A-end head pad and head brace. No breach.

3(b) Thermally damaged top fittings.

3(c) Flames from top fitting protective housing and manway area.

Table A-4: Tank Car TILX 731462

Consist order	**48**
Orientation in the consist	B
Heads	No damage.
Shell	Significant jacket tearing, wrinkling, and thermal damage (Figure 4c).
Bottom outlet valve	Thermally damaged but intact and closed.
Top fittings, PRD and Manway	Top fittings protective housing separated from flange. Liquid valve, vapor valve, PRD stripped from flange (4a). Remaining bolts bent toward B-end. Manway gasket thermally destroyed. Manway cover coated with carbon (Figure 4b).
Stub sills	A-end stub sill torn off outboard of the head brace.
Breach/ Loss of Product	Thermal and mechanical / 10,567 gallons.



4(a). Top fittings flange, missing protective housing, missing valves and PRD.

4(b). Thermally destroyed manway gasket and carbon on interior of manway cover.

4(c). Thermally damaged manway and sheared shop fittings.

4(d). Flames from top fittings area.

Table A-5: Tank Car TILX 731464

Consist order	**49**
Orientation in the consist	A
Heads	B-end head fractured horizontally about 1 ft above the head pad (5x6 hole), deformed outward (Figure 5c). Flap of head material at the right side of the breach was bent inward with fracture surfaces angular and on slant planes. Impact mark identified at the bottom of the B-end head shield (5b)
Shell	Significant jacket tearing, wrinkling, and thermal damage.
Bottom outlet valve	Sheared off – valve ball still in place. BOV Skid intact.
Top fittings, PRD and Manway	Top Fittings and protecting housing sheared off. No damage. PRD did not activate.
Stub sills and couplers	B-end coupler fractured and severed from shank. B-end stub sill torn off.
Breach/ Loss of Product	Mechanical and thermal / full loss of product (28,935 gallons)
Additional notes	Car was pinched between 48 and 50. Head blown out (Figure 5a)

5(a). Crushed shell material, top and left side.

5(b). B-end head shield, impact mark (circled).

5(c). Fractured/torn B-end head with outward deformation of material.

Table A-6: Tank Car TILX 731426

Consist order	**50**
Orientation in the consist	A
Heads	No damage
Shell	Bottom of tank punctured between the bottom reinforcing bats about 2 ft. beyond the A-end side of the BOV skid structure. Tank buckled inward at the puncture location (Figure 6a) Breach was a 2-inch angular hole along with a 6-inch long (through-wall) crack. A 2-inch gouge led to the hole from the A-end side of the tank.
Bottom outlet valve	Skid structure intact and ball valve closed (Figure 6b)
Top fittings, PRD and Manway	Manway thermally damaged.
Stub sills	No recorded damage
Breach/ Loss of Product	Mechanical and thermal / 15,465 gallons

6(a). Tank puncture A-end bottom center, 2 ft. beyond BOV skid structure.

6(b). Buckled tank bottom and BOV skid structure.

6(c). Flame in area of tank puncture, bottom center A-end side of BOV.

Table A-7: Tank Car TILX 731748

Consist order	**51**
Orientation in the consist	B
Heads	B-end head sustained large, rounded dent from A-end impact of (52) TILX731754 (Figure 7a).
Shell	About 28 inches of B-end head pad A-1 and A-2 welds were fractured. The head pad separated from the tank about 1 inch. There was no visual evidence of material breaching (Figures 7b and 7c)
Bottom outlet valve	The bottom of the eduction pipe brace became disconnected from the sump and pipe shifted, impacting the back of the BOV (Figure 7d). BOV was plugged by emergency responders.
Top fittings, PRD and Manway	Manway and top fittings housing were scorched and covered with carbon. One of the manways bolts had been broken. Top surfaces of the tank jacket in this area were scorched red.
Stub sills	B-end stub sill fractured at the head brace weld.
Breach/ Loss of Product	Mechanical and thermal / 19,297 gallons

7(a). B-end head, rounded dent, fractured stub sill.

7(b). Fractured A-2 head pad weld and separated head pad.

7(c). Fractured A-1 and A-2 head pad welds and cracked head brace-to-head pad weld.

7(d). Flared (impact damaged) eduction pipe bottom as seen through the open bottom outlet ball valve.

7(e). Flame from manway and top fittings housing.

Table A-8: Tank Car TILX 731739

Consist order	**54**
Orientation in the consist	A
Heads	A-end head shield torn with breach
Shell	A-end head/shell was torn from the knuckle radius-inboard at about 2:00(A-L top), creating a 12-in x 20-in breach. (Figure XX)
Bottom outlet valve	BOV skid collapsed on the A-end side of the structure and BOV valve saddle sheared off (Figures 8a and 8b). The eduction pipe was separated from the sump flange and offset by about 12-in. The flange was positioned over the BOV. (Figure 8c)
Top fittings, PRD and Manway	Thermally damaged manway gasket
Stub sills and coupler	B-end coupler upper shelf sharp radius exhibited an impact witness mark (Figure 8e)
Breach/ Loss of Product	Mechanical and thermal / 28,935 gallons

8(a). Collapsed portion of skid protection structure with bottom outlet valve missing.

8(b). Separated 3-inch top valve0 with impact damage.

8(c). Eduction pipe flange over BOV opening.

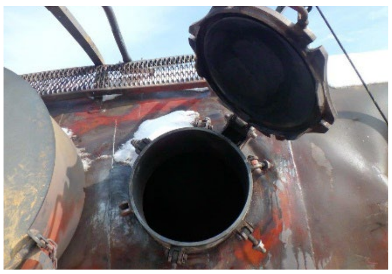
8(d). Thermally damaged manway gasket material.

8(e). B-end coupler upper shelf sharp radius witness mark.

8(f). Flame at A-end head/shell tear.

Table A-19: Tank Car TILX 731726

Consist order	**55**
Orientation in the consist	A
Heads	No damage
Shell	Jacket around manway and top fittings housing scorched red.
Bottom outlet valve	No damage
Top fittings, PRD and Manway	Manway gasket thermally damaged and cracked. Carbon deposits on the interior of the manway cover (Figures 9a and 9b).
Stub sills	No recorded damage
Breach/ Loss of Product	Thermal / 19,447 gallons



9(a). Thermal damage to tank jacket around the manway.

9(b). Internal surface of manway cover with thermally damaged gasket.

9(c). Flame from manway and top fittings protective housing.

Table A-10: Tank Car CRDX 300077

Consist order	**56**
Orientation in the consist	A
Heads	No damage
Shell	Tank shell punctured on the lower B-R side. Angular flaps of shell material were pushed inward, leaving a hole about 5-ft 4-in x 2-ft 8-in.
Bottom outlet valve	No damage
Top fittings, PRD and Manway	All top fittings and valves removed post derailment for tear-down and examination at Trinity facility (Saginaw, TX). (Figure 10b). Carbon deposits found in the PRD vapor space (Figure 10c), communication pipe, liquid valve seat and throat of the eduction pipe. Liquid valve gasket appeared thermally damaged (Figure 10d).
Stub sills	No recorded damage
Breach/ Loss of Product	Mechanical and thermal / 28,930 gallons
Additional notes	Car pinched between 55 and 57

10(a). Top fittings flange after removal of fittings for bench testing.

10(b). Top fittings valves, PRD, and VRD removed for examination.

10(c). Carbon deposits on internal surface of PRD vapor space communication pipe.

10(d). Thermally damaged liquid valve gasket.

Table A-11: Tank Car CRDX 300073

Consist order	**57**
Orientation in the consist	A
Heads	No damage
Shell	Top surfaces of jacket around manway and top fittings sustained thermal damage
Bottom outlet valve	• BOV skid protection structure deformed by a shallow longitudinal dent through the middle of the A-end side of the bottom surface (Figure 11a)). • Flashing was bent toward the B-end. • Structure outboard right edge of the (A-end side) sustained an impact mark and gouge (Figure 11b) BOV stem adapter was bent, not broken, at the breakage groove showing evidence of torsional fracture with the top slotted portion of the adapter severed and missing (Figure 11c)
Top fittings, PRD and Manway	Area round top fittings and manway were thermally damaged
Stub sills	B-end stub sill was bent about 20-degrees to the right.
Breach/ Loss of Product	Thermal / 28,937 gallons

11(a). BOV skid protection structure, shallow dent A-end side (right side in photo).

11(b). Skid protection structure impact mark, A-R side of skid structure.

11(c). BOV stem adaptor with top surface torsional fracture. Slotted end was severed and missing.

11(d). Repaired B-end right A-2 head pad fillet weld.

11(e). Flames in manway

area.

Table A-12: Tank Car TILX 731429

Consist order	**59**
Orientation in the consist	A
Heads	No damage
Shell	Jacket sustained thermal damage. Large (16x6) dent in the side of car (Figure 12a).
Bottom outlet valve	Adaptor sheared off – ball still in place. BOV Skid intact.
Top fittings, PRD and Manway	Thermally damaged fittings and gaskets
Stub sills	No recorded damage
Breach/ Loss of Product	Thermal / 6,345 gallons

12(a). A-end head with head shield and jacket removed.

12(b). A-end head pad and head brace, no visible weld cracks.

12(c). Flames in manway area.

Table A-13: Tank Car CRDX 300056

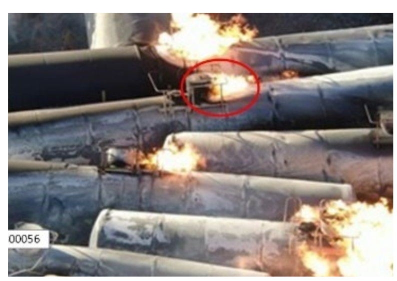
Consist order	**60**
Orientation in the consist	A
Heads	No damage
Shell	Head brace-to-head pad weld was cracked along its outboard surface on the head pad. (Figure 13d).
Bottom outlet valve	• The bottom outlet valve packing had melted, leaving an extruded mass of Teflon protruding from the annular space of the open ball valve (Figure 13a). • Eduction pipe and flange separated from the sump and positioned about the BOV (Figure 13a). • BOV nozzle extension sheared off and hanging by the safety chain. Skid protection structure on B-side was bowed/dished inward at its center. Two impact marks located on the right edge of the structure (Figure 13b). BOV operating handle extension was bent and separated from the valve stem adapter sleeve (Figure 13c).
Top fittings, PRD and Manway	Top fittings thermally damaged
Stub sills	No recorded damage
Breach/ Loss of Product	Thermal / 16,596 gallons

13(a). Mass of melted and extruded Teflon ball valve packing and eduction pipe flange seen through the BOV hole.

13(b). B-side skid protection structure. Impact marks on right side, dished in the middle. The separated BOV nozzle was hanging from the safety chain.

13(c). Bent and separated BOV operating handle extension.

13(d). No breaching damage identified at the B-end stub sill inboard at tail piece following jacket removal.



14(e). Flames from top fittings protective housing.

Table A-14: Tank Car CRDX 300019

Consist order	**61**
Orientation in the consist	B
Heads	Large, rounded center dent over the entire head (Figure 14a).
Shell	10x10 dent on A-L side. Jacket has thermal damage
Bottom outlet valve	Tank jacket around the BOV skid scorched and thermally damaged. BOV handle extension engaged and BOV adapter in stem slot. Noted by FRA/Trinity inspection as leaking with nozzle cap still attached to the valve.
Top fittings, PRD and Manway	Thermal damage to manway and top fittings (Figure 14c).
Stub sills and couplers	A-end stub sill fractured at the head brace (Figure 14b).
Breach/ Loss of Product	Thermal / 17,948 gallons

14(a). Rounded dent to A-end head as seen after head shield removal.

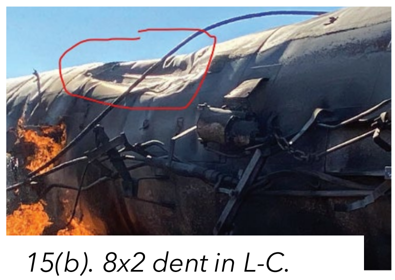
14(b). Fractured stub sill web at head brace and head pad. No tank breaching damage in this area.

14(c). Flames at top fittings protective housing, manway, and bottom outlet valve areas.

Table A-15: Tank Car CRDX 300093

Consist order	**62**
Orientation in the consist	B
Heads	No damage.
Shell	8x2 dent in L-C.
Bottom outlet valve	Thermally damaged. Leaking through burned out seats and gaskets. BOV leg sheared (Figure 15c).
Top fittings, PRD and Manway	Manway thermally damaged.
Stub sills	No recorded damage.
Breach/ Loss of Product	Thermal / 3,389 gallons

15(a). Flames at bottom outlet valve and manway.



15(b). 8x2 dent in L-C.

15(c). BOV active leak with fire due to burned out seats and gaskets.

Table A-16: Tank Car TILX731751

Consist order	**63**
Orientation in the consist	A
Heads	A-end head shield and jacket were removed for inspection (Figure 16a). The head sustained three dents. The lower dent (directly above the stub sill) measured 60-in x 32 ¼-in x 8-in deep (Figure 16b). The upper right side of the head sustained a dent that measured 65-in x 80-in x 12-in deep. The upper left side of the head sustained a dent that measured 69-in x 70-in x 12-in deep. The A-end head pad fractured around the HAZ of the head brace attachment fillet weld. The head pad peeled away from the tank. The A-3 rectangular stub sill to head pad "window weld" appears to have penetrated the tank and the weld did not crack as the tank was pulled away from the stub sill. The tank fractured around the A-3 weld, opening a hole as the tank was deformed upward by a dent (Figures 16a-16h).
Shell	Shell breach through A-end head. Jacket around the B-L side of the manway was scorched.
Bottom outlet valve	No damage.
Top fittings, PRD and Manway	Thermal damage to the top fittings and interior surface of the protective housing (figure 16i).
Stub sills	The left and right A-end stub sill web was torn and peeled in both transverse directions. The left half of the head brace fillet weld to the top stub sill plate was fractured (Figure 16c). The inboard sill pad A-15 weld measured 10.5 mm thick (as measured by Vernon Walker, FRA). The left inboard sill pad leg fillet weld measured 6 mm, while the right leg fillet weld measured 8 mm. Weep holes near the stub sill tail piece indicated the pad was fitted flush with the tank in this area.
Breach/ Loss of Product	Mechanical and thermal / 28,917 gallons

16(a). A-end head after head shield and jacket removal.

16(b). A-end stub sill and head damage.

16(c). Fractured A-end head beneath fractured and separated head pad.

16(d). A-3 window weld, viewing the interior surface of the stub sill top plate.

16(e). Stub sill web damage.

16(f). A-15 inboard sill pad weld.

16(g). A-end head after stub sill/head pad/tank section was removed for laboratory examination.

16(h). Evidence no. HMD22LR001-HAZ-002, stub sill/head pad/tank section.

16(i). Flame from top fittings and manway area. The breached A-end head is to the right in this photograph with no flames visible in that area.

Table A-17: Tank Car TILX 731741

Consist order	**64**
Orientation in the consist	A
Heads	No damage
Shell	No shell breach.
Bottom outlet valve	Nozzle sheared, saddle and valve intact. Handle and adapter intact.
Top fittings, PRD and Manway	Tank jacket around manway and top fittings housing was scorched red. Manway covered coated in carbon. Thermal damage to all.
Stub sills and couplers	A-end stub sill broken at head brace and missing from the car. Left sub sill web piece torn from the entire length of the head brace. Right fractured stub sill web piece was bent to the right about 90 degrees (Figure 17a). Left-forward corner of the A-3 fillet weld was cracked about 2-in with no tank breaching observed (Figure 17b). A-3 fillet weld thickness measured 5mm inboard side and 10mm outboard side.
Breach/ Loss of Product	Thermal / 25,695 gallons

17(a). The A-end stub sill was fractured from the head brace with a piece of its broken web bent to the right.

17(b). Cracked A-end A-3 weld, left forward corner.

17(c). A-end head pad and head brace. The head pad A-1 and A-2 welds were not fractured.

17(d). A-end inboard stub sill tail pieces. The measured A-7 fillet weld was adjacent to the white photo-tape.

17(e). Flame in area of top fittings housing and manway.

Table A-18: Tank Car TILX731758

Consist order	**65**
Orientation in the consist	B
Heads	No damage.
Shell	Jacket sustained thermal damage
Bottom outlet valve	No damage.
Top fittings, PRD and Manway	Manway and top fittings housing surrounded by scorched jack (red). Manway gasket found hanging loose from an open manway cover (Figure 18c). Damaged manway gasket collected for lab exam.
Stub sills	B-end coupler sheared off. A-end stub sill twisted.
Breach/ Loss of Product	Thermal / 18,451 gallons

18(a) A-15 weld measurement location.

18(b). A-end stub sill/head pad.

18(c). Scorched jacket surrounding manway and top fittings housing. Thermally damaged gasket material was hanging loose from the open manway.

18(d). A-end breach location as indicated by flames in aerial imagery.

18(e). Flame indicates undocumented breaching damage at A-end head/shell interface, about 2:00.

Table A-19: Tank Car TILX 731762

Consist order	**66**
Orientation in the consist	B
Heads	B-end head pad A-1 and A-2 fillet welds cracked, but head pad did not separate from the tank (Figure 19a). B-end head was punctured about 12-in above and to the right of the stub sill (Figure 19b). The puncture was an angular 4-inch-long tear within a shallow dent. There was a 1- to 2-inch-long gouge in the head material above this tear.
Shell	B-end head/ shell puncture – angular 4-inch tear with shallow dent
Bottom outlet valve	Eduction pipe and mounting flange were displaced from the sump and situated behind the ball valve 19(c)
Top fittings, PRD and Manway	PRD gasket was thermally damaged/ destroyed. Liquid valve gasket was thermally damaged. Manway area thermally damaged.
Stub sills and couplers	A-end coupler shank pushed upward. The top draft sill plate was torn and bent upward. Both A-end draft gear bottom carrier plates were deformed downward.
Breach/ Loss of Product	Mechanical and thermal / 22,445 gallons

19(a). B-end head pad with cracked A-1 and A-2 fillet welds.

19(b). B-end head puncture and gouge.

19(c). Displaced eduction pipe and flange as seen through BOV hole (investigators removed the bottom outlet valve from the flange).

19(d). Flame from B-end head puncture and manway area.

Lines 67 through 72 were located at a siding in Vernon, Texas, about seven miles from the incident site. These tank cars were part of the unit train but did not derail, however, sustained some thermal damage as a result of being in close proximity to the pool fire. The cars were disconnected and transferred to the siding where they were inspected with the following observations:

Line 67: TILX731744

- The bottom outlet valve nozzle cap was loose and was removed by hand.
- The manway swing bolts were tool tight[12].

Line 68: CRDX300055

- The bottom outlet valve nozzle cap was loose and was removed by hand.
- Manway cover swing bolts were tool tight.

Line 69: CRDX300072

- The bottom outlet valve nozzle cap was loose and was removed by hand.
- 4 manway cover swing bolts were loose.
- PRD did not activate.
- The manway swing bolts were tool tight.

Line 70: CRDX300101

- The bottom outlet valve nozzle cap was loose and was removed by hand.
- 4 manway cover swing bolts were loose.

Line 71: TILX731458

- The bottom outlet valve nozzle cap was loose and removed by hand.
- gasket material was thermally damaged. Gasket fragments were collected for laboratory examination, evidence control number HMD22LR001- HAZ-006.
- PRD had actuated.

Line 72: TILX731757

- The bottom outlet valve nozzle cap was loose and was removed by hand.
- 1 of 6 manway cover swing bolts was loose.
- The manway gasket was crushed, cut and out of position in the manway cover groove. The mechanically damaged gasket was collected for laboratory examination, evidence control number HMD22LR001-HAZ-007.

[12] Made tight by the use of a bar, wrench or other suitable tool.