National Transportation Safety Board
Washington, D.C. 20594

Report Date: April 14, 2016

Hazardous Materials Group Factual Report

A. Accident Identification

Carrier:	BNSF Railway Company
Train No.:	U TIOCXP0 44T
Location:	Heimdal, North Dakota
Date/Time:	May 6, 2015, at 7:30 a.m.
NTSB No.:	DCA-15-FR-009

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A. Accident Summary

On Wednesday, On May 6, 2015, about 7:30 a.m. central daylight time, a BNSF crude oil unit train traveling at approximately 45 mph derailed due to a broken wheel. The train consisted of 109 cars (107 loaded tank cars and 2 buffer cars on the head end), and three locomotives at the front of the train. Six tank cars derailed. As a result, five of the derailed tank cars were breached and caught on fire. The derailment was about a mile east of Heimdal, North Dakota near the 45th Avenue crossing in Wells County, ND. The fire resulting from the derailment required the evacuation of all residents from the town of Heimdal and surrounding rural residents (approximately 30 individuals) due to heavy smoke creating respiratory health concerns. Evacuated residents were directed to the Fessenden City Hall for shelter, but most opted to stay with friends or relatives located away from the impacted area. The smoke plume extended to the north requiring notification of the Manitoba Emergency Measures Organization. Tank cars that were not damaged or derailed were uncoupled at each end from the damaged railcars (including three locomotives) and were moved from the scene. Damages were estimated to be $3.5 million as of October 2015. Weather at the time of the accident was 57 degrees and overcast skies.

Figure 1: Derailment location, Heimdal, North Dakota.

B. Summary of Train Route on May 6th

BNSF Railway Company train U TIOCXP0 44T was a unit train and "key train"[1] with three locomotives, two buffer cars and a total of 107 loaded tank cars containing petroleum crude oil,

[1] Definition of "key train" is provided by Association of American Railroads (AAR) publication OT-55-N, *Recommended Railroad Operating Practices for Transportation of Hazardous Materials*. "Key trains" have speed restrictions and other operating criteria. According to the BNSF Hazardous Materials Instructions for Rail, a key

which is designated by the U.S. Department of Transportation (DOT) as a Class 3—flammable liquid. The train was transporting a shipment of Bakkan crude oil to Philadelphia Energy Solutions Philadelphia, PA on the KO subdivision.[2]

C. Shipper

The shipment of crude oil on May 6th was offered by Hess Trading Corporation, who is a global energy company primarily engaged with the exploration and production of crude oil and natural gas.[3] Hess Tank Cars LLC's entire tank car fleet consists of 962 CPC-1232, non-jacketed tank cars. The shipment on May 6th originated from Hess North Dakota Export Logistics LLC's Tioga Rail Terminal facility, which is a crude oil and natural gas liquids (NGL) rail loading facility. This terminal consists of a dual loop track designed to load two crude oil unit trains per day, or approximately 140 MBbl/d. The terminal also consists of ladder tracks designed to load 30 MBbl/d of NGLs with track space for over 250 rail cars and three crude oil storage tanks with a combined shell storage capacity of 287 MBbls.

At the Tioga terminal, 50% of the crude oil is transported from the well head by pipeline and 50% by tank truck. Hess North Dakota Export Logistics LLC contracts with Watco Transloading LLC to provide transloading services at the Tioga Rail Terminal. Watco personnel control, monitor, record, and report on the operation of the Tioga Rail Terminal. Watco personnel also provide inspection, crude oil loading, railroad consulting, inventory management, repair, data reporting, general maintenance and technical support and safety compliance services.

a. Pre-Accident Events: Loading Procedures

The Watco personnel told NTSB investigators that they generally maintain about 3-percent outage, or filling limit when loading tank cars with crude oil. Federal regulations at 49 CFR 173.24b require no less than 1% outage for materials other than TIH/PIH. The loaders use a formula to achieve 3% or less than the shell capacity of the tank. The Hess Accuload™ system automatically dispenses a temperature-corrected quantity of lading to the rail car.[4] The loaders document the car number, car capacity, tank heel measurement, post filling stick measurement, product density, and product temperature on the tank car inspection and loading form. The amount in barrels dispensed by the Accuload system and security seal numbers are also recorded on the inspection form.

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train includes a train with "A. One (1) or more car loads of Spent Nuclear Fuel (SNF) or High Level Radioactive Waste (HLRW) moving under the following Hazardous Material Response Codes (STCCs) - 4929142, 4929143, 4929144, or 4929147, or B. One (1) or more tank car loads of Poison or Toxic Inhalation Hazard (PIH or TIH) (Hazard Zone A, B, C, or D), anhydrous ammonia (UN1005), or ammonia solutions (UN3318), or C. Twenty (20) or more car loads (including intermodal portable tank loads) of any hazardous material."

[2] The KO Subdivision is part of the Northern Transcon, which is a route operated by BNSF Railway. The KO subdivision runs between Dilworth, ND to Minot, ND.

[3] Hess Corporation: http://www.hess.com/company

[4] Accuload is computer software for calculating and controlling loads.

Prior to loading the cars, regulation 49 CFR 173.31(d) require the shipper to inspect and document the following in accordance with regulation 49 CFR 174.9, which requires the carrier to inspect for required markings, labels, placards and securement of closures and leakage.

Watco personnel use a multi-item tank car inspection checklist for loading operations at the Tioga Rail Terminal.

Before loading operations:

- Damaged or missing safety devices
- Presence of bad orders
- Wheel defects such as cracks, chips, holes, shelling, or flat spots
- Truck assembly defects, and condition of springs
- Damage to couplers and striker plate
- Legible marking and stenciling
- Placarding
- Secured bottom outlet cap and plug, and condition of gasket
- Closed and secured bottom outlet valve
- Outer tank shell dents, corrosion, cracks, or other defects
- Signs of leaks

During loading operations:

- Signs of crude oil leaks at seams, fittings, or valves
- Signs of air leaks in vacuum relief valve or pressure relief valve
- Plugs and caps attached to chains
- Chains properly secured to tank car
- Fittings and devices under dome cover properly tightened and secured with no sign of leaks

After loading operations:

- Bottom liquid valve closed, valve plug and cap secured
- Manway properly closed and secured
- Ball valves in closed position and secured
- Protective housing cover closed and secured
- Proper seals applied

Watco personnel perform this same inspection each time a train is loaded at the Tioga Rail Terminal. Additional inspections are conducted at various yards, terminals and destinations along each train's route.

D. Hazardous Materials Involved in the Derailment

Each car on the train contained crude oil from the Bakken region of North Dakota. The six hazardous materials tank cars that derailed in the accident were in positions 81 through 86 of the

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107 total tank cars in the train; five of which released product. The sixth de-railed car was re-railed. None of the remaining tank cars containing crude oil were derailed or breached in the accident.[5]

a. Crude Oil

Crude oil is primarily a mixture of hydrocarbons that exists in a liquid state with dissolved gases in natural underground reservoirs. Petroleum products, such as diesel and gasoline, are produced from the processing of crude oil and other liquids at petroleum refineries. Other products, like natural gas, are also produced from the extraction of liquid hydrocarbons at natural gas processing plants or the finishing of petroleum products at blending facilities. [6]

Crude oil involves a highly complex combination of hydrocarbons; heteroatomic compounds of nitrogen, oxygen, and sulfur[7]; organometallic compounds; inorganic sediment and water. The composition is highly variable and no crude oil has the same specifications. The hydrocarbon compounds present in crude oil vary by region but are typically presented by percentages of the following four main groups of hydrocarbons:

Paraffins	15%-60%
Napthenes	30%-60%
Aromatics	3%-30%
Asphaltics	~ 6%

The petroleum industry generally classifies crude oil by its geographical source, such as Bakken Crude Oil, which comes from the Bakken formation, which is a geological formation that extends through North Dakota and Montana, as well as some Canadian provinces. Other types of crude oil come from different regions such as the Alaskan North Slope, West Texas Intermediate, Cold Lake blend in Alberta, Canada, and many others regions around the world. The industry typically distinguishes these type of crude oils by its sulfur content (sweet vs. sour), and API gravity (light vs. heavy density).[8] These characteristics determine which type of refinery can process the crude oil into a refined petroleum product.

Light crude oils typically have a low viscosity and high API gravity and generally produce a higher percentage of gasoline and diesel fuel when processed in a refinery. The extra heavy oils have a high viscosity and a low API gravity. [9] The Bakken crude oil typically is a light crude oil, also known as a "tight" oil, because it comes from a rock formation such as shale or tight sandstone that has low permeability and requires unconventional methods for drilling, such as hydraulic fracturing[10,11]

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[5] BNSF U-TIOCXPO-44T, Provisional Mass Balance by Car-Updated May 8th, 2015
[6] EIA FAQs: http://www.eia.gov/tools/faqs/faq.cfm?id=40&t=6
[7] Heteroatomic compounds are chemical compounds that do not have carbon or hydrogen in the ring structure.
[8] API Gravity is the specific gravity of an oil, which is calculated by the ratio of the density of oil to density of water at a specific temperature of 60 °F.
[9] "Heavy Oil and Natural Bitumen Strategic Petroleum Resources", USGS, http://pubs.usgs.gov/fs/fs070-03/fs070-03.html
[10] Shale or Tight oil in the United States and Canada is considered an unconventional oil because traditionally was considered difficult or costly to produce.

The shipper's safety data sheet (SDS) describes the "light sweet crude oil" as an extremely flammable liquid. Human exposure to crude oil can cause eye, skin and respiratory conditions. The SDS also indicates that it is extremely toxic to aquatic life with long-term effects. The SDS lists wide ranges for the boiling point (86.2 °F -1000+°F), flash point (50 °F -199.4 °F), and vapor pressure (i.e. volatility) (12.6-13.3 psi @100 °F). These characteristics indicate that crude oil is a Class 3—flammable liquid, in accordance with the definition in 49 CFR Part 173.120(a).[12]

The shipper applied the widely used technical standard, ASTM D86 *Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure* to determine the boiling point, and ASTM D56, *Standard Test Method for Flash point by Tag Closed Cup Tester* for flash point, and ASTM 6377, *Standard Test Method for Determination of Vapor Pressure of Crude Oil: VPCRx (Expansion Method)*, for vapor pressure. PHMSA mandates that these chemical and physical properties be considered for proper classification of the material, tank car selection, safety and security planning and railroad operational controls.[13]

b. Crude Oil Characteristics Research

In March 2015, Sandia National Laboratories (Sandia) released a report, "Literature Survey of Crude Oil Properties Relevant to Handling and Fire Safety in Transport." The U.S. Department of Energy (DOE) and Department of Transportation are seeking to better understand and to mitigate risks associated with the increase of rail transport of crude oil, tight oil in particular. The DOE commissioned Sandia Laboratories to evaluate the material properties of crude oils, specifically crude oil coming from the Bakken region of North Dakota. The scope of the problem was whether the volatility of tight oils, such as Bakken crude oil, contributed to the combustion events that were occurring during a rail transportation of crude oil. The Association of American Railroads reported that more than 621,000 crude oil tank car shipments occurred in 2014, whereas annual shipments of crude oil remained steady through 2009 at approximately 12,000 per year.[14] Train derailments have been occurring with corresponding greater frequency.

The literature survey was the first step to review what information was available on the relationship between chemical and physical property data of crude oil and potential for ignition, combustion and explosion. The survey found an abundance of information on crude oil properties, however, found that the data yielded little to be able to compare different crude oils and their relationship to their physical hazards. It also concluded that the severity of an accident depended on a number of variables, in addition to volatility, such as the volume of fuel, surrounding infrastructure and other environmental factors. Sandia also identified inconsistencies

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[11] "Golden Rules for a Golden Age of Gas, World Energy Outlook Special Report on Unconventional Gas", International Energy Agency, 2012.

[12] Class 3 Flammable Liquid under Part 173 means a liquid having a flash point of not more than 140 °F or any material in a liquid phase with a flash point at or above 100 °F that is intentionally heated and offered for transportation or transported at or above its flash point in a bulk packaging.

[13] "Amended and Restated Emergency Restriction/Prohibition Order", U.S. Department of Transportation, Docket NO. DOT-OST-2014-0025 (March 6, 2014).

[14] *Annual Report of Hazardous Materials Transported by Rail 2014*, Association of American Railroads (July 2015).

regarding the sampling and testing methods that could potentially lead to the misclassification and ultimately risk transporting these materials in insufficiently protected containers.

To answer some of the questions identified in the literature survey, Sandia developed a Sampling, Analysis and Experiment (SAE) plan in its next step to its research on crude oil characteristics. The SAE plan involves the following six tasks to be conducted over the next few years:

1. Review and Evaluation of New and Emerging Crude Oil Characterization Data
2. Sampling Method Evaluation
3. Initial Combustion Experiments and Modeling
4. Crude oil Characterization-Tight Oil versus Conventional Oil
5. Large-Scale and Rail Car Combustion Testing and CFD Modeling
6. Comprehensive Sampling, Analysis and Experiment [15]

c. Testing Methods used for crude oil

ASTM D86, *Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure*, is used to determine the boiling range of refined petroleum products by performing batch distillation. According to the method, the boiling range of hydrocarbons provides information on the composition, the properties, and the behavior of the fuel during storage and use.[16] This standard is referenced in 49 CFR Part 173.121(a)(2)(i) for determining hazard class and packing group assignment for flammable materials.[17]

ASTM D7169, *Standard Test Method for Boiling Point Distribution of Samples with Residues such as Crude Oils and Atmospheric and Vacuum Residues by High Temperature Gas Chromatography*, is used to calculate the boiling range distribution of hydrocarbons in stabilized crude oil using high temperature gas chromatography.[18] Sandia noted in its literature survey that this standard alone is not recommended for application to tight crude oils, like the Bakken crude oil, because they contain significant quantities of dissolved gases and light hydrocarbons.[19]

ASTM D7900, *Standard Test Method for Determination of Light Hydrocarbons in Stabilized Crude Oils by Gas Chromatography*, is used to determine the boiling range distribution of hydrocarbons in stabilized crude oil. According to the standard, the results from this test method

[15] Department of Energy, "Crude Oil Characteristics Research", http://energy.gov/fe/articles/crude-oil-characteristics-research.
[16] ASTM D86-15, Standard Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure, ASTM International, West Conshohocken, PA, 2015, www.astm.org.
[17] ASTM D86-15, Standard Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure, ASTM International, West Conshohocken, PA, 2015, www.astm.org.
[18] Stabilized crude oil is defined as having a Reid Vapor Pressure equivalent to or less than 82.7 kPa.
[19] ASTM D7169-11, Standard Test Method for Boiling Point Distribution of Samples with Residues Such as Crude Oils and Atmospheric and Vacuum Residues by High Temperature Gas Chromatography, ASTM International, West Conshohocken, PA, 2011, www.astm.org.

combined with results of Test Method D7169 to give a full boiling point distribution of a crude oil.[20]

ASTM D56, *Standard Test Method for Flash point by Tag Closed Cup Tester*, is used to determine the flash point of flammable and combustible materials, as specified by shipping and safety regulations. This standard is referenced in 49 CFR Part 173.120(c)(i)(A).[21]

ASTM D6377, *Standard Test Method for Determination of Vapor Pressure of Crude Oil: VPCRx (Expansion Method)* is used to determine the vapor pressure of crude oil for shipping and storage. Vapor pressure refers to the materials evaporation characteristics. It is important to crude oil producers and refiners for general handling and initial refinery treatment. The method used is an automated cylindrical measurement chamber to determine the vapor pressure exerted in a vacuum of crude oils.[22] This method is an approved method under EPA regulations to determine true vapor pressure.

ASTM D323, *Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method),* is used to determine the vapor pressure for gasoline, volatile crude oils and other volatile petroleum products in a vapor chamber at 37.8 °C (100 °F). The sample acquired is in an open container.[23]

ANSI/API RP 3000, *Classifying and Loading of Crude Oil into Rail Tank Cars*, is a Recommended Practice published by the American Petroleum Institute. The document provides guidance on the material characterization, transport classification, and quantity measurement for overfill prevention when loading the tank cars with crude oil.[24]

d. Sampling Methods used for crude oil

ASTM D4057, *Standard Practice for Manual Sampling of Petroleum and Petroleum Product*, is a standard practice that covers procedures and equipment for manually obtaining samples of liquid petroleum crude oil. It addresses the sampling of semi-liquid or solid state petroleum products and provides information about sample container selection, preparation and sample handling. This standard is referenced in ASTM D323.[25]

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[20] ASTM D7900-13e1, Standard Test Method for Determination of Light Hydrocarbons in Stabilized Crude Oils by Gas Chromatography, ASTM International, West Conshohocken, PA, 2013, www.astm.org

[21] ASTM D56-05(2010), Standard Test Method for Flash Point by Tag Closed Cup Tester, ASTM International, West Conshohocken, PA, 2010, www.astm.org.

[22] ASTM D6377-15, Standard Test Method for Determination of Vapor Pressure of Crude Oil: VPCRx (Expansion Method), ASTM International, West Conshohocken, PA, 2015, www.astm.org.

[23] ASTM D323-15a, Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method), ASTM International, West Conshohocken, PA, 2015, www.astm.org.

[24] ANSI/API Recommended Practice 3000, Classifying and Loading of Crude Oil in Rail Tank Cars, 1st Edition, September 2014, American Petroleum Institute, Washington, D.C., www.api.org.

[25] ASTM D4057-12, Standard Practice for Manual Sampling of Petroleum and Petroleum Products, ASTM International, West Conshohocken, PA, 2012, www.astm.org.

ASTM D5842, *Standard Practice for Sampling and Handling Fuels for Volatility Measurement*, is a standard practice that covers procedures and equipment for obtaining, mixing and handling representative samples of volatile fuels.[26]

ASTM WK49954, *New Practice for Manual Piston Cylinder Sampling of Volatile Crude Oils, Condensates and Related products*, is a new ASTM standard that is being developed that specifically covers equipment and procedures for obtaining a representative sample of live or high vapor pressure crude oils, condensate and/or related petroleum products from low pressure sample points, when there is insufficient sample point pressure to use a floating piston cylinder.[27]

E. Petroleum Crude Oil Sample Evidence

The identification of the physical and chemical characteristics of crude oil is necessary for determining the proper hazardous materials classification and assignment of packing group, and selection of a proper container (rail car). According to the train consist, the shipper classified the crude oil at Heimdal as Packing Group I, Class 3 – flammable liquid, UN 1267. Packaging group assignment criteria is determined by U.S. regulation, 49 CFR 173.121, which specifies the flash point and initial boiling point of each packing group, as indicated in Table 1.

Table 1. Packing Group Assignments, 49 CFR 173.121

Packing group	Flash Point	Initial Boiling Point
I		≤35 °C (95 °F)
II	<23 °C (73 °F)	>35 °C (95 °F)
III	≥23 °C, ≤60 °C (≥73 °F, ≤140 °F)	>35 °C (95 °F)

Misclassification could lead to the use of unauthorized tank cars that may lack required safety features, insufficient safety and security plans, and inaccurate hazard communications to emergency responders.

The crude oil shipment transported on the accident train was shipped as a Packing Group I. Hess collected a composite sample of the crude oil contained in BNSF train U TIOCXP0 44T and submitted it for testing on May 6, 2015. Table 2 provides the analytical results.

[26] ASTM D5842-14, Standard Practice for Sampling and Handling of Fuels for Volatility Measurement, ASTM International, West Conshohocken, PA, 2014, www.astm.org.
[27] ASTM WK49954, http://www.astm.org/DATABASE.CART/WORKITEMS/WK49954.htm.

Table 2. Hess testing results of the crude oil from the May 6, 2015 shipment.

Test Method	Parameter	Result
ASTM D56	Flash Point	<50 ° F
ASTM D6377	Vapor Pressure VPCRx (expansion method)	10.83 psi
ASTM D86	Distillation Initial Boiling Point	81.8 ° F

PHMSA Investigators on May 9, 2015, collected 2 samples from the Hess Tioga terminal and also collected another four samples from five tank cars of the incident train once they arrived at the Philadelphia terminal on May 28, 2015; however, only three samples were found usable for laboratory analysis from that day. PHSMA used a piston cylinder as the sampling instrument.[28] PHMSA submitted samples for laboratory analysis to determine classification characteristics, the results are indicated in Table 3.

Table 3. PHMSA Test Results from samples taken on May 9 and May 28, 2015.

Date of Samples Taken	Sample ID	Flash Point (°F)	Boiling Point (°F)	Vapor Pressure (psi)
May 9, 2015	WN15.00568.001	< 73	85.8	10.01
May 9, 2015	WN15.00568.002	< 73	88.7	10.08
May 28, 2015	WN15.0068.001	< 73	N/A	10.57
May 28, 2015	WN15.0068.002	< 73	92.5	10.61
May 28, 2015	WN15.0068.003	N/A	N/A	11.77
May 28, 2015	WN15.0068.004	N/A	N/A	11.24

The PHMSA tests results for flash point and boiling point fall into the range for Packing Group I criteria.

Hess also collected samples on May 9, 2015, using an open bottle grab method but the samples were reported lost during its transfer to the designated laboratory.

F. Crude Oil Stabilization/Conditioning

To reduce crude oil vapor pressure, a process called "oil stabilization" or "oil conditioning" separates the oil and gas. The process involves extracting the crude oil and feeding it into a three

[28] A piston cylinder is a device used to maintain separation between the liquid sampled and the backpressure inert gas. This instrument is used to prevent the loss of volatile components in a material, such as crude oil, to reflect accurate test results when analyzing for certain physical properties such as vapor pressure, flash point, and boiling point.

phase separator that splits the water, gases and crude oil (See Figure 3). Stabilization occurs throughout the supply chain and is intended to reduce the volatility of the crude oil by removing gaseous and light fraction hydrocarbon compounds. Conditioning typically occurs at the well-site and is intended to typically eliminate non-hydrocarbon compounds from the oil that lack fuel value or unnecessarily elevate the hazard level of the petroleum, e.g. toxic hydrogen sulfide. However, this process can also eliminate highly volatile compounds that reduce the vapor pressure of the crude oil. While the two processes appear to have similar outcomes, the operating limits and equipment are different.[29]

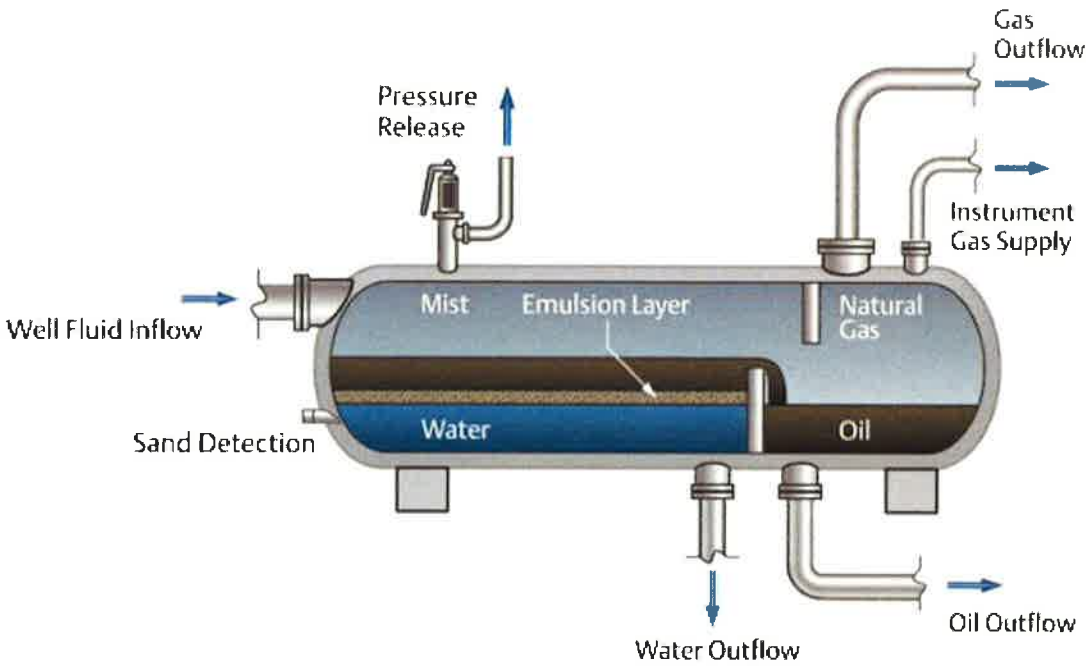

Figure 2. General Process Diagram of the Oil and Gas Separator.

Hess reported that they have been performing oil conditioning for its crude oil since the 1950s. Unlike the simplified process as depicted in Figure 2, Hess process involves either a single well or multi well operation that uses a 2-phase separator that heats the crude oil and splits the gas, oil and water. The oil is fed into a tank farm and the gas is sent to either a flare or a vapor recovery system that is then directed to a natural gas processing. Hess' stabilization process reduces the vapor pressure of its crude oil to an approximate 11 psig, though the company reported that it may rise slightly higher to 13 psig in the winter season.

The North Dakota Industrial Commission (NDIC) passed an "Oil Conditioning" order in December 2014, which took effect on April 1, 2015. The order requires production facilities to reduce the vapor pressure of crude oil to 13.7 psig or less. [30] According to the NDIC, the intent of this order was to establish conditioning standards and impose provision to improve

[29] *Literature Survey of Crude Oil Properties Relevant to Handling and Fire Safety in Transport*. Sandia Report, Sandia National Laboratories (March 2015).
[30] North Dakota Industrial Commission, Order No. 25417.

transportation safety and marketability of crude oil. At the time of the accident on May 6, Hess measured the load transported at a vapor pressure of 10.8 psig. Hess reported that while it has been conditioning its crude oil before the order was issued, the state rule required the oil company to increase the temperature of its conditioning process so that a greater portion of the volatile compounds were removed from the crude oil. However, Hess submitted to PHMSA vapor pressure data of Bakkan crude oil samples that were tested in accordance with ASTM D323 six months prior to the NDIC order being passed, which reflected vapor pressures still under 13.7psi.

Report of Analysis

Client: HESS Corporation
Job Location: North Dakota
Sample Designated As: Bakken Crude
Vessel/Location: North Dakota

Representing:	DATE TESTED	SAMPLE #	Vapor Pressure 122°F, 0.02 V/L (ASTM D6377)	Vapor Pressure 100°F, 4.00 V/L (ASTM D6377)	ASTM_D323
TRT 14-11-2 TIOMU072	11/7/2014	1	26.28	11.34	12.00
UTOMUO-716	11/21/2014	2	27.28	13.34	12.10
TRT Submitted	12/10/2014	3	26.65	13.61	9.20
TIOMU085 Unit G, TIOMU086 Unit H	12/20/2014	4	25.43	13.43	12.70
TIOMU090 Unit G	1/5/2015	5	30.45	12.27	13.30
TIOCXPO-04T	1/17/2015	6	27.47	12.60	12.00
UTIOMUO-04 Unit F	2/2/2015	7	23.82	11.89	11.70
UTIOMUO-08 Pot A	2/13/2015	8	25.35	12.83	13.00
TRT 15-0216 TIOMU011 Unit I	2/20/2015	9	28.34	11.82	13.10
TRT 15-0303 Unit D, TIOAWA008T	3/10/2015	10	27.12	13.28	13
TIOCXPO-17T Pot A	3/20/2015	11	27.62	13.45	12.3
TRT 15-6-31	4/6/2015	12	23.24	12.58	12.1
UMUT10-025	4/20/2015	13	21.24	11.54	10.1
Bi-Weekly (sample pot)	5/4/2015	14	22.26	10.77	10.10

Figure 3. Hess Oil Bakken crude oil data from November 2014 through May 2015.

G. Tank Car Descriptions

a. Derailed Tank Cars

All of the derailed tank cars were general service specification DOT-111A100W1 constructed to the AAR CPC-1232 standard. They had a maximum gross rail load (GRL) of 286,000 pounds. Table 4 provides a summary of tank car information retrieved from the certificates of construction and the Universal Machine Language Equipment Register (UMLER) report (See Table 4).

LINE NO.	FIELD INDEX #	REPORTING MARK	BUILDER	BUILD DATE	DOT SPECIFICATION (Stencil)	MATERIAL HEAD/SHELL	HEAD AND SHELL THICKNESS	PRD (STD)
81	3	TRFX 1224	Union Tank Car	7/28/2011	DOT111S100W1	TC 128-B NORM	0.500 & 0.531	165 psi
82	5	TRFX 1176	Union Tank Car	7/18/2011	DOT111S100W1	TC 128-B NORM	0.500 & 0.531	165 psi
83	1	TRFX 1374	Union Tank Car	8/29/2011	DOT111S100W1	TC 128-B NORM	0.500 & 0.531	165 psi
84	2	TRFX 1056	Union Tank Car	6/11/2011	DOT111S100W1	TC 128-B NORM	0.500 & 0.531	165 psi
85	4	TRFX 1170	Union Tank Car	7/15/2011	DOT111S100W1	TC 128-B NORM	0.500 & 0.531	165 psi
86	6	TRFX 1044	Union Tank Car	6/13/2011	DOT111S100W1	TC 128-B NORM	0.500 & 0.531	165 psi

Table 4. Summary of tank car build information for six hazardous materials tank cars that derailed in the accident.

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

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

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

[31] N.O.S. stands for not otherwise specified.

must be at least 1/2-in. thick. In all cases the cars must be equipped with at least 1/2-in. half-head shields.

DOT-111 tank cars manufactured to the CPC-1232 standard are not required to be equipped with thermal protection systems to protect the tank from exposure to pool or torch fire conditions that can occur in accidents. On May 1st, the U.S. DOT issued a new rule that requires certain, non-jacketed DOT-111 tank cars used to transport flammable materials with puncture resistance and thermal protection systems to the new DOT 117R or 117P standard. Title 49 CFR Part 173.243 requires that non-jacketed CPC-1232 tank cars, such as the cars involved in this accident, in Packing Group I HHFT service must be retrofitted or removed from service by April 1, 2020.

H. Tank Car Damages

The RJ Corman Railroad Group removed the tank cars off the track and staged them in a field south of the derailment location. The Hazardous Materials Group inspected the tank cars and recorded observations and measurements. The Group also determined the resting orientation of the tank cars based on site examination, photographs, and the AEI data from Station Minot (see Figure 4). [32]

Figure 4: Aerial view of the accident scene.

Summary of the damages to the five tanks are as follows: Two (2) tank cars sustained punctures from impact with objects in the derailment sequence, one (1) tank car released material from an

[32] AEI or Automatic Equipment Identification is an electronic recognition system used in the railroad industry that provides the original orientation of the rail car in the train.

open bottom outlet valve, Three (3) tank cars sustained punctures from impact with objects in the derailment sequence, while two (2) of the cars sustained thermal tears on the order of 10 to 11-inches in length. The major damages to each car and the details for how the crude oil released from each car are detailed below:

Line 81, TRFX 1224

Observations:

- Contents of tank car released through partially opened bottom outlet valve (See Figure 5).
- Cracked head pad fillet weld on the A-end of the head of the tank car.
- Headshield was detached from the A-end.
- Shell had scorched paint.
- No damage observed to the pressure relief devices.

Figure 5: TRFX 1224 (81) Bottom Outlet Valve as found

Line 82, TRFX 1176

Observations:

- Partial contents of tank car released through a 10 in. thermal tear on the B-end. Shell thickness around the tear was measured with a Hess Corporation ultrasonic thickness gauge ±.005 tolerance. Thinnest measurement adjacent to tear was .245″ (See Figure 6).
- L-shaped gouge 12 in. in diameter that was also 12 inch above the head shield on the B-end head.
- 60" inch dent found in the center of the B-end.
- Shell had scorched paint.
- Bottom outlet valve (BOV) was found closed, handle was sheared off.
- No damage observed on the pressure relief devices.

Figure 6: TRFX 1176 (82) Thermal Tear

Line 83, TRFX 1374

Observations:

- Mechanical shell tear 12 foot long x 6-inches wide on the bottom of the tank car, releasing all of its contents (See Figure 7).
- Head shield impact, bolter web bent and 18-inches long x 4-inches wide puncture on the B-end.
- Bolster web bent on the A-end
- Top half of the shell had scorched paint.
- No damage observed to the BOV; operating handle was broken away.
- No damage observed on the pressure relief devices.

Figure 7: TRFX 1374 (83) Mechanical Tear Bottom Center of Car and B-R Head

Line 84, TRFX 1056

Observations:

- Contents released through a 10-in. wide mechanical tear (See Figure 8).
- Dents 24-inches long x 27-inches wide above half head shield on the A-end.
- Head shield broken free from B-end; impact damage.
- No damage observed to the BOV; handle was fully open, nozzle was closed.
- Upper half of the shell had scorched paint.
- No damage observed on the pressure relief devices.

Figure 8: TRFX 1056 (84) Puncture to B-End Head

Ex3127-0018-VAN

Line 85, TRFX 1170

Observations:

- Partial contents released through 11-in x 2-in thermal tear (See Figure 9). Tank shell bulged near the tear.
- Shell had scorched paint.
- No damage observed on the pressure relief devices.
- No damage observed to the BOV.

Figure 9: TRFX 1170 (85) Thermal Tear

Line 86, TRFX 1044

Observations:

- No accident damage observed. Car re-railed (see Figure 10).

Figure 10: TRFX 1044 (86)[33]

I. Applicable Tank Car Regulations

The following federal regulations applied to the accident tank cars:

Title 49 of the Code of Federal Regulations (CFR) Part 179 outlines the federal requirements for tank cars. Subpart B of Part 179 contains general design requirements, while Subpart D contains the specifications for non-pressure tank car tanks (classes DOT-111AW and 115AW). 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, with the exception of CPC 1232 standards.

[33] Courtesy of Federal Railroad Administration

Other hazardous materials regulations pertinent to loading and use of tank cars include:

- Part 173.24(b) - outage and filling requirements for bulk packaging. Liquids must be loaded with at least one percent outage of the total capacity of a tank car at the reference temperature of 115°F for a non-insulated tank.
- Part 180, Subpart F - qualification and maintenance of tank cars. Tank cars are required to successfully pass periodic inspections at a frequency determined by the type of tank car and the products transported. Such inspections include, but are not limited to, the following:
  - Internal and external visual inspection of the tank shell and heads for abrasion, corrosion, cracks, dents, distortions, defects in welds, or any other condition that makes the car unsafe for transportation.
  - Structural integrity inspections and tests, including transverse and fillet welds at certain locations on the tank using non-destructive testing techniques Thickness of tank shell and heads to within specified tolerances in Part 180.509 (g)
  - Testing of pressure relief devices.

a. Pressure Relief Devices (PRD)

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

b. Tank Material and Thickness

DOT-111 tank cars can be fabricated out of several plate materials that must meet the specifications that are outlined in 49 CFR 179.200-7. The tank cars in this incident were made of carbon steel plates. The standard provides that the carbon steel heads and shells must be constructed of TC 128 Grade B steel or A516-70 steel.[34] The specification requirement for DOT-111A100W1 requires a minimum plate thickness of 7/16 inch thickness.[35] These tank cars did not require thermal insulation, although it is optional, or tank-head puncture resistance systems such as jackets or shields.[36]

The bulk packaging requirements in §173.243 for high-hazard liquids, state that DOT-111 tank cars and CPC-1232 tank cars are no longer authorized to transport Class 3 flammable liquid for

[34] Tank cars manufactured after the CPC – 1232 standard – normalized

[35] See 49 CFR 179.201-1 – Individual Specification Requirements

[36] See 49 CFR 179.201-1 and 49 CFR 173.31(b)(3) and (4) - In accordance with 49 CFR 173.31(b)(4), the tank cars that were involved in this accident were not required to have thermal protection systems. Only tank cars that are used to transport Hazard Class 2 and poison inhalation hazard materials are required by the Hazardous Materials Regulations to have thermal protection that conforms to the specifications of 49 CFR 179.18.

use in high-hazard flammable train (HHFT)[37] service unless retrofitted to the DOT Specification 117R retrofit standards, or the Specification 117P performance standards.

The retrofit standard of §179.202-13 applicable to the non-jacketed CPC-1232 tank cars involved in this accident requires the following modifications and features no later than April 1, 2020 if they are to be operated in an HHFT:

- Thickness of plates must be a minimum of 7/16-inch.
- Tank head puncture resistance system, full height headshield with minimum thickness of 1/2-inch.
- Thermal protection system conforming to §179.18 with reclosing pressure relief device.
- Jackets covering the thermal protection system, minimum 11 gauge thickness.
- Bottom outlet valve designed to prevent unintended opening in accidents.
- ECP brakes if operated in a high hazard flammable unit train (HHFUT).[38]

c. HM-251

On May 8, 2015, PHMSA published its final rule, HM-251, "Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains." The rule was issued in response to the increase of train accidents in recent years that involved the release of a flammable liquid and resulted in a major fires and property damage. Both PHMSA and the Federal Railroad Administration developed HM-251 and put in place requirements for more accurate classification requirements for unrefined petroleum-based products, a more thorough routing risk analysis, improved notification procedures, reduced operating speeds, enhanced braking standards, and a new specification DOT-117 tank car with retrofit requirements that are to be implemented on a risk-based schedule. The scope of the rule targeted transportation of crude oil and ethanol in high-hazard flammable trains (HHFTs). The highest risk tank cars, DOT-111 tank cars in packing group I service) was required to be retrofitted or replaced by May 1, 2018 and the lowest risk tank cars, jacketed CPC-1232 tank cars in packing group I and II service and all remaining tank cars in packing group III service, to be DOT-117-compliant by May 1, 2025.

d. FAST Act

On December 4, 2015, the President signed the Fixing America's Surface Transportation Act (FAST Act). Section 7304 of the Act requires that all tank cars used to transport any Class 3 flammable liquids shall meet the DOT-117, DOT-117P, or DOT-117R specifications in 49 CFR Part 179, regardless of train composition. The Act kept a similar implementation schedule for continued use of tank cars in crude oil and ethanol service as was provided in the PHMSA rule, HM-251 with that fleet being fully DOT-117 compliant by May 1, 2025. However, the Act

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[37] Effective July 7, 2015, *High-hazard flammable train (HHFT)* means a single train transporting 20 or more loaded tank cars of a Class 3 – flammable liquid in a continuous block or a single train carrying 35 or more loaded tank cars of a Class 3 – flammable liquid throughout the train consist.

[38] High-hazard flammable unit train (HHFUT) means a single train transporting 70 or more loaded tank cars containing Class 3 – flammable liquid.

added provisions pertaining to other Class 3 materials to require retrofitting or removal from service of tank cars transporting Packing Group I flammable materials by May 1, 2025, and Packing Groups II and III flammable materials by May 1, 2029.

Section 7305 of the FAST Act further directs the Department of Transportation (DOT) Secretary to issue regulations within 180 days that require that each tank car built to meet the DOT-117 specification and each non-jacketed tank car modified to meet DOT-117 specifications be equipped with an insulating blanket with at least ½-inch thick of DOT approved material.

Section 7309 of the FAST Act mandates the Crude Oil Characteristics Research Sampling, Analysis, and Experiment Plan study to be completed by Sandia National Laboratories in conjunction with the Department of Energy and the Department of Transportation. Once the study is completed, a report must be submitted to Congress on the results and recommendations of the study. The recommendations, which are based on the findings of the study, are to address regulations and legislations to improve safe transport of crude oil.

J. Post-Accident Events

Emergency Response Activities

The Volunteer fire departments from the communities of both Harvey and Fessenden responded to the accident on May 6th. The Harvey firefighters received the call from dispatch around 7:35am to act as mutual aid to the Fessenden firefighters. The Harvey and Fessenden departments formed a unified command structure and assessed the situation. The Harvey fire department assumed that the material was crude oil and consulted the Emergency Response Guide (ERG) for guidance. The decision was made to take a defensive stance and evacuate nearby residents through a reverse 9-1-1 order because of the aggressive nature of the fire. Firefighters also went door-to-door to evacuate the community. The Harvey fire department reported that the fire raged for approximately three hours until BNSF contractor Wenck and Associates, arrived with chemical foam to fight the fire. Between 9-9:30pm, the major fire and residual pool fires were extinguished. Air monitoring was conducted by representatives from another contractor, Center for Toxicology and Environmental Health (CTEH). They determined the environment was safe and allowed residents to return to their homes.

The NTSB interviewed both the Fessenden and Harvey Fire Departments. Their observations and role in the response to the accident were recorded and a transcript will be prepared and placed in the docket for this investigation. The information they provided to NTSB investigators included the following:

- Harvey FD was dispatched at 07:35. The state dispatcher advised the fire chief that rail tank cars were on fire. They arrived on-scene within about 15 minutes of being notified.
- The accident occurred about a ¼ mile outside of Heimdal, ND.
- Harvey FD is a 40-member volunteer fire department. About 30 of the members responded.
- Harvey was being dispatched into the Fessenden, ND fire district as mutual aid response.

- Fire departments from seven communities within the area responded and included the communities of: Harvey, Fessenden, Animus, Drake, New Rockford, Carrington, and Devils Lake.
- On arrival, Harvey FD approached within 1/3 mile south of the tracks, just close enough to observe site conditions from over a hill. Fessenden FD staged north of the tracks.
- Harvey FD evacuated Heimdal within 10 minutes of their arrival on scene via a door-to-door notification.
- A unified command was initially established between the Fessenden and Harvey FDs.
- The Devils Lake Rapid Response Team (RRT) advised the Harvey fire chief to increase the distance between his firefighters and the scene. A major concern was four 1,000 gallon propane tanks (used by the railroad for switch heaters), which were very close to the fire. Therefore, the Harvey chief directed that an incident command perimeter be established about 1 mile from the derailment scene. The Devils Lake team had attended the Association of American Rail Road's Transportation Technology Center Inc. (AAR) (TTCI) training in Pueblo, Colorado, and was very knowledgeable about tank cars, thus serving as a valuable resource for the Harvey fire chief.
- TRANSCAER® training that the Harvey fire chief completed, informed him to increase his distance between his firefighters and the scene and to allow the fire to burn. He followed this guidance on the day of the accident.
- Fessenden FD contacted the train crew and obtained the original train consist. Fessenden communicated the consist information to Harvey FD.
- Fessenden fire fighters approached within sight of the propane tanks and maintained a constant watch of the propane tanks to ensure their integrity was not being compromised by the heat from the adjacent fire.
- Harvey, ND Sheriff's Department and representatives from the County Roads Department maintained scene control by blocking traffic access to the accident area.
- Between 11:00 and11:30, the Harvey FD assisted railroad employees by providing them turnout gear and SCBA so they could isolate the west line of tank cars from the burning cars as far as possible to avoid a cascading event. They reported the heat from the fire was not as intense at that time.
- Challenges faced by the fire department included the long delay in having senior BNSF representatives on the scene. By the time BNSF representatives arrived at 17:00, the intensity of the fire had diminished considerably. Additionally, there was significant delay in moving the west cut of cars because an engine could not approach until damaged track was repaired.
- Contract and local firefighters allowed the fire to burn until about 18:30-19:00. The intensity was low enough at this time to safely allow resources to address the remaining small pool fires and provide water to cool the tank cars. During this process, Harvey FD shuttled 52,000 gallons of water to the BNSF fire services contractors, Specialized Response Solutions (SRS), and to Wenck and Associates personnel.

- The Harvey fire chief initially assumed he was responding to crude oil based on his knowledge of rail transportation in his community. The fire chief stated that any tank car train heading from west to east is typically loaded with crude oil, while he knew them to be empty when traveling from east to west; whereas, a mixed freight train would be more of a concern because of the possibility of anhydrous ammonia or chlorine cars being present.
- Representatives from the Harvey fire department did reference the U.S. DOT, Emergency Response Guidebook to check recommended evacuation distances.
- Foam was available on site within a couple of hours, however the members of the unified command decided that it would be best to allow the fire to consume much of the released oil.
- The fire burned strongly for about 3 hours then rapidly became less intense. The Harvey fire chief could not understand why the fire did not continue to burn strongly because not all of the oil in the breached tank cars had been consumed.

K. Accident Injuries

There were no injuries involved with the accident.

L. Site Cleanup and Waste Disposal

About 96, 486 gallons of crude oil was estimated to have been released after the accident. Table 6 provides the values that were used to calculate this number.

LINE NUMBER	CAR NUMBERS	FIELD NUMBER	LADING VOLUME AT LOADING (GAL)	RECOVERED VOLUME (GAL)	LOST VOLUME (GAL)	APPROXIMATE OUTAGE (%)
81	TRFX 1224	3	30,047	900	29,147	3.7
82	TRFX 1176	5	30,065	24,360	5,705	3.4
83	TRFX 1374	1	30,056	0	30,056	3.7
84	TRFX 1056	2	30,060	11,842	18,218	3.9
85	TRFX 1170	4	29,950	16,590	13,360	3.9%
TOTALS					**96, 486**	

Table 6. Summary of the volumes of crude oil lost or recovered.

The site cleanup and waste disposal was handled by a number of BNSF contractors. The following contractors were hired:

- Pinnacle
- WCEC
- Beltrami Services
- Specialized Response Solutions (SRS)
- R.J. Corman Railroad Group
- Wenck and Associates
- CTEC
- Arcadis
- Bay West/Hulcher

BNSF developed a site containment and recovery plan and submitted the plan to on-scene representatives from the U.S. Environmental Protection Agency (EPA). The plan included activities for recovery operations to contain migration of contaminated materials on the north and south side of the track. The activities included excavation of contaminated soil, use of vacuum trucks, and boom and absorbent pads to recover pockets of pooled oil. Air and water monitoring were also conducted. Cleanup costs as of October 2015 are estimated at $4.5 million dollars.

EPA monitored the cleanup and determined that of the total amount released, approximately 30,000 gallons were estimated to have burned. The rest flowed on the north side of the track and into a ditch on the south side of the tracks. A designated wetlands area was located on the north side of the tracks. Since hard and absorbent booms were set in place early in the response, the migration of oil was contained. BNSF contractors implemented an air monitoring program and included sampling for both volatile organic compounds (VOCs) and particulate matter in the contaminated area and the town of Heimdal.

The fire was allowed to burn itself out allowing crews to maintain water through the night to cool the tanks. This allowed personnel access to remove the remaining oil in the tank cars. Hess and the owners of the tanks sent the five derailed cars to be dismantled and scrapped once a post-examination had been completed.