WHITE PAPER

WILLIAMS FIRE & HAZARD CONTROL

Bakken Crude Testing

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tyco Fire Protection Products

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Introduction

Bakken Crude comes from a deposit of light oil in the Bakken Formation of North Dakota and Canada. Discovered in 1951, it is considered to be the single largest oil formation in the United States. In the mid 2000's, as oil prices increased and improved drilling techniques were discovered, barrels of Bakken Crude flowed out of the ground. More oil increased the demand for transportation. With most oil pipelines operating at full capacity, trains provided a needed resource. As more trains moved crude oil through the countryside, the number of derailments increased, some with railcars containing Bakken Crude. Only some of the derailments had railcars that ruptured and burned. One of the worst derailments occurred in Lac-Mégantic, Quebec, Canada when a runaway train with multiple cars containing Bakken Crude left the tracks resulting in multiple ruptured cars which burned and exploded in the center of a small town.

The local fire department of this small town and many surrounding fire departments were not properly prepared for a hydrocarbon fire of this size and had limited supplies to fight this brutal fire. While the fire departments sought help, the fire continued to burn with intermittent explosions. Finally, answers and resources were obtained for controlling and extinguishing the fire. It took approximately another four hours to move the suppressing agent and equipment to the site, and another hour to setup. After several hours of applying the correct suppressing agent with proper equipment, the fire was extinguished. When the fire was over, concerns emerged claiming Bakken Crude had a more volatile chemistry, causing it to be more resistant to firefighting efforts.

Bakken Crude is light crude requiring less refining than heavier crude oils. During transportation the chemical makeup of any crude oil may change as stratification occurs with lighter oil moving to the top. Lighter crude oils are more likely to release fumes which are highly flammable and explosive. Because crude is a hydrocarbon based petroleum product, a special foam concentrate formulation is required for extinguishment. Applying water or inappropriate suppression agents to such a fire may be inefficient and may likely intensify and spread the fire.

Chemical Properties

A recent study submitted to the U.S. Department of Transportation by the American Fuel & Petrochemical Manufacturers shows that vital factors, such as flash point, vapor pressure, boiling point, corrosivity, and sulfur content of Bakken Crude (see Table 1), closely resemble crude oil produced in Texas and other regions of the world for decades.

Table 1: Bakken Crude Oil

Characteristics	Reported Values	Hazmat Transportation Regulatory Implications
Flashpoint	Range: -138.2 °F to 122 °F (-59 °C to 50 °C)	Bakken crude oils meet the criteria for Packing Group I, II, or III flammable liquids or as combustible liquids[1]
Initial Boiling Point	Range: 36 °F to 152.4 °F (2.2 °C to 66.9 °C)	Bakken crude oils with an initial boiling point of 95 °F (35 °C) or less meet criteria for Packing Group I flammable liquids; others for Packing Group II or III flammable liquids or combustible liquids according to flashpoint
Vapor Pressure at 122 °F (50 °C)	Maximum: 16.72 psia (1.15 bar)	All Bakken crude oils have a vapor pressure limit below 43 psia (2.96 bar) at 122 °F (50 °C)[2] and must be transported as liquids
Reid Vapor Pressure at 100.4 °F (38 °C)	Maximum: 15.4 psia (1.06 bar)	Not used by the regulations; confirm the vapor pressure at 122 °F (50 °C) is well below the above 43 psia (2.96 bar) limit and Bakken crude oils must be transported as liquids
Rail tank car pressures on delivery	Maximum: 11.3 psig (0.779 bar)	Demonstrates Bakken crude may be safely transported in DOT specification 111 tank cars[3]
Flammable gas content	Maximum: 12.0 liquid volume %	None; with the vapor pressures of all Bakken crude oils examined not exceeding a vapor pressure of 43 psia (2.96 bar), all Bakken crude oils examined must be transported a liquids
Hydrogen sulfide content in the vapor space	Most reported H_2S concentrations were below the OSHA STEL; one reported a maximum level of 23,000 ppm	None when low values are experienced; additional hazard communication to warn of the presence of H_2S when inhalation hazard levels are encountered[4]
Corrosivity	NACE B+ or B++	Data and experience indicate Bakken crude oil does not corrode steel at a rate of 1/4 in. per year or more so that Bakken crude oil is not a corrosive liquid

Footnotes:

1 Note the Bakken crude data submitted (approximately 1400 samples) included only one sample that qualified as a combustible liquid, which has a lower risk than other flammable liquids.

2 Hazardous Materials Regulations: 43.5 psi (2.96 bar) vapor pressure threshold limit.

3 §179.201-1 Title 49 of the Code of Federal Regulations Parts 105 to 180, provides summary specifications for DOT-111 rail tank cars. Earlier DOT 111's were designed to a 240 psig (16.5 bar) burst pressure whereas later designs are designed to a minimum burst pressure of 500 psig (34.5 bar). Based on §179.15(b)(2)(ii) the minimum pressure relief valve settings for tank cars with a minimum burst pressure of 240 psig (16.5 bar) is 35 psig (2.4 bar) and for 500 psig (34.5 bar) designs the minimum setting is 75 psig (5.2 bar).

4 See §172.327 Title 49 of the Code of Federal Regulations Parts 105 to 180.

Purpose and Activities of the Test

On behalf of first responders, railroads, and government officials, and to evaluate the effectiveness of standard firefighting techniques on Bakken Crude, Williams Fire & Hazard Control, a service arm of Tyco Fire Protection Products, presented an information session with a controlled burn of the crude oil. Attendees included Regulatory and Safety professionals representing a cross section of America's Rail, Government (DOTD) and Oil & Gas sectors. The event was held November 11, 2014, at the Beaumont Emergency Services Training Complex (BEST), Beaumont, Texas.

Following round table discussions related to flammability, response measures of municipal departments, and regulations; two large controlled Bakken Crude oil burns provided observation of the fire characteristics and the impact of proper foam application for hydrocarbon crude oil.

The Center for Toxicology and Environmental Health (CTEH) was also on site to conduct real-time air monitoring and analytical air sampling of the crude oil burn. No detections above the site-specific action levels outlined in the Air SAP were observed; and no exceedences of occupational exposure guidelines were observed. See Appendix for the Executive Summary of the CTEH report.

Bakken Crude Live Burn Facts

Results Overview: Two tests using different portable handheld equipment, which provide a coordinated ground assault, extinguished the 42 ft (12.8 m) diameter fires with more than 1,280 gal (4845 L) of Bakken Crude in just over 3 and 5 minutes respectively.

Origin of product tested: Bakken Formation North Dakota

Gallons of pure Bakken Crude Oil purchased for test: 3,500 U.S. Gallons (13,249 L)

Test site: Beaumont Emergency Service Training Complex (BEST) Beaumont, Texas, USA

Test container: 42 ft (12.8 m) diameter Petroleum Storage Tank Simulator with water bottom

Weather conditions:	November 11, 2014	S.E. Wind at 8.5 mph (13.7 kph)
	70 °F (21.1 °C)	Partly Cloudy

PRE-BURN
PETROLEUM STORAGE TANK SIMULATOR 42 FT (128 m) DIAMETER

Test #1: Handline Nozzles

Product:	1,288 gal (4876 L) Bakken Crude (Approx. 1.5 in. (38 mm)) over water bottom
Pre-Burn:	1 Minute, 18 Seconds
Equipment:	Handline Nozzles
Foam Concentrate:	THUNDERSTORM 1% x 3% AR-AFFF W801A (New formulation with specialty short chain C6 fluorochemical and hydrocarbon surfactants, polymers, and solvents)
Foam Application Hardware:	2 Nozzles at 95 gpm (360 L) each
Foam Application Rate:	0.13 gpm/ft^2 (5.3 Lpm/m^2)
Fire Extinguished:	**3 Minutes 16 Seconds**

Williams Fire & Hazard Control professional firefighters worked together to apply the 1% foam solution. As the fire cooled, the team cautiously advanced using simple techniques similar to a novice application. Keeping the streams close reduced the disturbance of the crude while laying down the foam blanket. Continuous application cooled the crude and expanded the foam blanket until escaping vapors were reduced and all flames were extinguished.

TWO TEAMS WITH HANDLINE NOZZLES

Test #2: Portable Ground Monitor Nozzle

Product:	1,718 gal (6503 L) Bakken Crude (approximately 2 in. (51 mm)) over water bottom
Pre-Burn:	1 Minute 7 Seconds
Equipment:	Portable Ground Monitor Nozzle
Foam Concentrate:	THUNDERSTORM 1% x 3% AR-AFFF W801A (New formulation with specialty short chain C6 fluorochemical and hydrocarbon surfactants, polymers, and solvents)
Foam Application Hardware:	1 Monitor Nozzle at 221 gpm (837 L)
Foam Application Rate:	0.16 gpm/ft^2 (6.52 Lpm/m^2)
Fire Extinguished:	**5 Minutes 22 Seconds**

The portable ground monitor nozzle was assembled on site at a safe distance from the fire (approximately 75 ft (22.9 m). The 1% foam solution was mixed at 0.5% to demonstrate an unintentionally weak mix rate that might occur in the field. Continuous application cooled the crude and expanded the foam blanket until escaping vapors were reduced and all flames were extinguished. Post extinguishment shell cooling with handline nozzles, interrupted the foam blanket causing a reflash fire. The foam quickly re-healed and extinguished the fire.

ONE TEAM WITH PORTABLE GROUND MONITOR NOZZLE

Summary

For the response community, these tests shed light on some very important issues:

- Bakken Crude appears to have the same challenging fire dynamics as other crude oil products.
- With the right equipment and proper fire response measures, extinguishment of large-scale flammable liquid fires can be safely and quickly accomplished.
- There is an urgent need to supply proper equipment and provide flammable liquid firefighting training to municipal fire professionals and volunteers. This will improve response outcomes when fighting crude oil fires, especially in higher probability/higher consequence areas where immediate response is required.

Williams Fire & Hazard Control has been a leading industrial response force for nearly 40 years. Responding to some of the world's largest industrial fires, Williams Fire & Hazard Control has fought to eliminate the immediate threat to life and property, while also mitigating the potential extended impact that could be caused by a "runaway event." These response efforts require specialized foam and mobile response equipment, and response tactics that address the flammable liquid's fire chemistry.

With a successful history of fire response in all operational environments of the oil and gas life cycle, Williams Fire & Hazard Control continues to apply its wealth of knowledge for delivering:

- Critical site assessments
- Emergency preplans
- Fire suppression engineering
- Customized mobile response equipment

For More Information Contact:

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List of Selected Witnesses to the Bakken Crude Test

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James Farner, Manager of Hazardous Materials Field Ops & ER, BNSF Railway

Mark Garvin, Fire Chief, Marathon Galveston Bay Refinery

Pete Greco, Lyondell Basell

William Griffith, Battalion Chief, NWFVC CHP Refinery

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Patrick Knight, Flammable Liquids Operations Manager, LPG Emergency Response Corp.

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Jim Scott, Battalion Chief, Tacoma Fire Department

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Tommy Wells, Sr. Emergency Response Coordinator, Sunoco Logistics

Charles Wolfe, Director- EHS, Deeprock Energy Resources LLC

Reference

Transportation Safety Board of Canada, Minister of Public Works and Governmental Services Canada. (2014). Railway Investigation Report: Runaway and main-track derailment (Report No. R13D0054). Gatineau QC K1A 1K8: Transportation Safety Board of Canada.

For additional information on this topic view/download the following documents:

Safety Brief: Bakken Crude Oil – Rail Response Considerations. International Association of Fire Chiefs, brief for safety alert issued by The Pipeline and Hazardous Materials Safety Administration (PHMSA). (January 2014). http://www.iafc.org/safetyBriefBakkenoil

Bakken Crude Properties. The North Dakota Petroleum Council Study, prepared by Turner, Mason & Company Consulting Engineers. (August 2014). http://www.ndoil.org/resources/bkn/

AFPM Report Shows Bakken Crude Characteristics Well Within Safety Standards for Current Rail Car Design. Report: A Survey of Bakken Crude Oil Characteristics Assembled For the U.S. Department of Transportation, Submitted by American Fuel & Petrochemical Manufacturers (AFPM), Prepared by Dangerous Goods Transport Consulting, Inc. (May 15, 2014). http://www.afpm.org/news-release.aspx?id=4230

Note: The converted metric values in this document are provided for dimensional reference only and do not reflect an actual measurement.

Appendix

Bakken Crude Oil Burn Demonstration Air Monitoring and Sampling Report

November 11, 2014

CTEH Project Number: 106829

Link to full report: https://cteh.sharefile.com/d/sb4d9d9d7dc049188

Executive Summary

On November 11, 2014, Center for Toxicology and Environmental Health (CTEH*) conducted real-time air monitoring and analytical air sampling in support of a controlled Bakken crude oil burn demonstration in Beaumont, TX performed in conjunction with Williams Fire and Hazard Control. To support this demonstration, members of the CTEH Toxicology Emergency Response Program (TERP*) arrived on site at 0900 on November 11, 2014, and approximately 1 hr. later, initiated air monitoring and air sampling within the confines of the Beaumont Emergency Service Training (B.E.S.T.) facility in accordance with the Air Sampling and Analysis Plan (SAP) developed prior to the demonstration. The demonstration involved two controlled burns, each approximately 6-8 minutes in duration, followed by rapid extinguishment by Williams Fire and Hazard Control personnel.

Throughout the duration of the demonstration, CTEH conducted real-time air monitoring using chemical-specific colorimetric detector tubes, RAE Systems MultiRAE and UltraRAE instruments, SidePak AM510s and radio-telemetering AreaRAE instruments. Real-time air monitoring was conducted for volatile organic compounds (VOCs), percent lower explosive limit (LEL), benzene, carbon monoxide (CO), nitrogen dioxide (NO2), sulfur dioxide (SO2), hydrogen sulfide (H2S), and particulate matter (as PM10). While detections of VOCs and particulate matter were observed during the demonstration, no detections above the site-specific action levels outlined in the Air SAP were observed.

To supplement real-time air monitoring efforts, CTEH collected integrated analytical air samples for volatile organic compounds (VOCs) and polynuclear aromatic hydrocarbons (PAHs) in addition to instantaneous (i.e. grab) samples for VOCs directly within the vicinity of the demonstration area. While no PAH detections were observed, a number of light hydrocarbons were detected downwind of the petroleum reservoir at concentration below the Texas Commission on Environmental Quality's (TCEQ) Short Term Air Monitoring Comparison Values. Additionally, two analytical VOC grab samples were collected in the headspace of the crude oil tanker truck to characterize the concentration of crude oil associated compounds that had volatile from the product. While a number of volatile hydrocarbons were observed, a comparison of the analytes concentration to its respective Critical Health Protective Value (CHPV) highlighted the relative importance of monitoring for benzene and hexane during situations involving crude oil spills or releases. In this regards, personal air samples collected on Williams Fire & Hazard Control personnel to assess the potential for exposure to benzene, toluene, ethylbenzene, xylene (BTEX), n-hexane, and aldehydes yielded detections of only three analytes (benzene, toluene and hexane). However, after adjustment for the period of exposure (100 minutes of an 8-hr work shift), no exceedences of occupational exposure guidelines were observed.

The CTEH TERP team demobilized from the B.E.S.T. facility following the conclusion of the demonstration at approximately 1230.

*CTEH and TERP are trademarks of Center for Toxicology and Environmental Health.