



OPERATIONAL SERVICES BRANCH
ENGINEERING LABORATORY REPORT

LP148/2013

Analysis of Crude Oil Samples

Montreal, Maine & Atlantic Railway, Train MMA-002

Date of Occurrence: 06-Jul-2013

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1.0 INTRODUCTION

1.1 Description of Occurrence

1.1.1 On 06 July 2013, a unit train carrying petroleum crude oil operated by Montreal, Maine & Atlantic Railway derailed in Lac-Mégantic, Quebec. Numerous tank cars ruptured and a fire ensued. The ambient air temperature at the time of the derailment was reported to be around 21°C.

1.2 Engineering Services Requested

1.2.1 A request was received from the Transportation Safety Board of Canada (TSB) Eastern Regional Operations - Rail/Pipeline office to analyze crude oil samples taken from selected tank cars.

2.0 EXAMINATION

2.1 Sampling Procedure

2.1.1 Crude oil samples were taken from selected tank cars under the direction of a TSB investigator. Table 1 summarizes the sampling details. Samples were collected from the 9 non-derailed tank cars at the end of the occurrence train (MMA-002) that were pulled back to Nantes, Quebec, after the derailment. In addition, samples were taken from 2 tank cars located at Farnham, Quebec, that were part of another unit train operated by Montreal, Maine & Atlantic Railway (MMA-874) that was transporting petroleum crude oil from the same origin as the occurrence train.

2.1.2 No attempt was made to collect samples from the derailed tank cars since all were exposed to the post-derailment fire to some extent. It was considered that this heat exposure would likely have caused volatile components of the crude oil to escape through breaches in the tank and/or during activation of the pressure relief device. Consequently, there was a high probability that any product samples collected from the derailed tank cars would not be representative of the lading prior to the derailment.

2.1.3 Prior to the collection of samples, the vapour space of each tank car was tested using a portable hydrogen sulphide gas detector. No measurable amount of hydrogen sulphide gas was detected.

Table 1: Crude Oil Samples

Car initial & number	Location collected	Date collected (YY-MM-DD)	Sampling method (see para. 2.1.4)	Quantity collected	Sample identification
NATX 310533	Nantes	13-07-07	A	250 mL 250 mL	NATX310533-A NATX310533-B
		13-08-07	C	1000 mL 1000 mL	NATX310533-C-TOP NATX31533-C-BOT
NATX 310595	Nantes	13-07-17	A	250 mL 250 mL	NATX310595-A NATX310595-B
		13-08-07	C	1000 mL 1000 mL	NATX310595-C-TOP NATX310595-C-BOT
NATX 310406	Nantes	13-07-23	B	250 mL	NATX310406
		13-08-08	C	1000 mL 1000 mL	NTAX310406-C-TOP NATX310406-C-BOT
WFIX 130629	Nantes	13-07-23	B	250 mL	WFIX130629
		13-08-08	C	1000 mL 1000 mL	WFIX130629-C-TOP WFIX130629-C-BOT
PROX 44211	Nantes	13-07-23	B	250 mL	PROX44211
		13-08-08	C	1000 mL 1000 mL	PROX44211-C-TOP PROX44211-C-BOT
NATX 310425	Nantes	13-07-23	B	250 mL	NATX310425
		13-08-08	C	1000 mL 1000 mL	NATX310425-C-TOP NATX310425-C-BOT
ACFX 73452	Nantes	13-07-23	B	250 mL	ACFX73452
		13-08-07	C	1000 mL 1000 mL	ACFX73452-C-TOP ACFX73452-C-BOT
NATX 310572	Nantes	13-07-23	B	250 mL	NATX310572
		13-08-08	C	1000 mL 1000 mL	NATX310572-C-TOP NATX310572-C-BOT
NATX 310487	Nantes	13-07-23	B	250 mL	NATX310487
		13-08-07	C	1000 mL 1000 mL	NATX310487-C-TOP NATX310487-C-BOT
				500 mL 500 mL	NATX310487-D-TOP NATX310487-D-BOT
NATX 303425	Farnham	13-07-25	A	500 mL	NATX303425
PROX 44169	Farnham	13-07-25	B	500 mL	PROX 44169

2.1.4 Three sampling methods (referred to as methods A, B and C in Table 1) were employed in accordance with ASTM D4057.¹ For method A, a middle sample² was collected using a glass pipette (¾-inch diameter, 60-inch long). For

¹ ASTM D4057-12 Standard Practice for Manual Sampling of Petroleum and Petroleum Products

² A middle sample is a sample taken from the middle tank's contents (a distance of ½ of the liquid depth below the liquid's surface) (refer to ASTM D4057)

method B, an upper sample³ was collected using a plastic bailer.⁴ For method C, a peristaltic pump was used to collect lower samples⁵ (identified by the suffix – BOT in Table 1) and upper samples (identified by the suffix –TOP in Table 1), after verifying that no stratification had occurred in the tank car. This was accomplished by collecting a vertical column of liquid representing the liquid in the tank using a COLIWASA in accordance with ASTM D5495.^{6,7} Visual inspection of the COLIWASA samples did not reveal any visible stratification.

2.1.5 All samples were transferred immediately from the sampling tool to glass bottles that were hermetically sealed and stored at ambient temperature until testing. Figure 1 shows 2 representative occurrence crude oil samples. The oil was a dark grey, greenish color.

2.1.6 The crude oil samples were sent for testing to 4 external laboratories – Core Lab.⁸, Maxxam Analytical⁹, AITF¹⁰ and Cassen.¹¹ The original analytical reports and certificates of analysis provided by the external laboratories are presented in Appendix A.

2.2 Flash Point Temperature

2.2.1 The flash point temperature is a measure of the tendency of a test specimen to form a flammable mixture with air under controlled laboratory conditions. The flash point is used in shipping and safety regulations to define flammable and combustible materials and to classify them according to their associated hazard.^{12,13} The flash point can indicate the possible presence of highly volatile and flammable constituents in a relatively nonvolatile or nonflammable material.

2.2.2 The ASTM D93 test methods cover the determination of the flash point of petroleum products in the temperature range from 40 to 370°C by a Pensky-Martens closed-cup apparatus.¹⁴ Values less than 40°C can be measured using the D93 procedure but the precision¹⁵ of such values has not been determined.

³ An upper sample is a sample taken from the middle of the upper 1/3 of the tank's content (a distance of 1/6 of the liquid depth below the liquid's surface) (refer to ASTM D4057)

⁴ The bailer was a 1-meter long by 2-inch diameter cylinder with bottom closure

⁵ A lower sample is a sample taken from the middle of the lower 1/3 of the tank's content (a distance of 5/6 of the liquid depth below the liquid's surface) (refer to ASTM D4057)

⁶ ASTM D5495-03(2011) Standard Practice for Sampling with a Composite Liquid Waste Sampler (COLIWASA)

⁷ The COLIWASA was ½-inch diameter, 11.6-foot long and made of polypropylene

⁸ Core Laboratories Canada Ltd., 2810 - 12th Street N.E., Calgary, Alberta T2E 7P7 (accredited to ISO 9001)

⁹ Maxxam Analytical, 6744 – 50 Street, Edmonton, Alberta T6B 3M9 (accredited to ISO/IEC 17025)

¹⁰ Alberta Innovates-Technology Futures, Fuels and Lubricants Laboratory, 250 Karl Clark Road, Edmonton Alberta T6N 1E4 (accredited to ISO/IEC 17025)

¹¹ Cassen Testing Laboratories, 51 International Blvd. Toronto, Ontario, M9W 6H3 (accredited to ISO/IEC 17025)

¹² Canada Transportation of Dangerous Goods Regulations Part II, Class 3 Flammable Liquids, 2.18 General and 2.19 Packing Groups

¹³ U. S. Code of Federal Regulations Title 49 Part 173.120 Class 3-Definitions and 173.121 Class 3-Assignment of packing group

¹⁴ ASTM D93-13 Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester

¹⁵ In this context, precision refers to the statistical control of the test method, that is the degree of agreement among measurements obtained within a single laboratory (repeatability) and between different laboratories

- 2.2.3 The ASTM D3828 test methods cover procedures for flash point of petroleum products and biodiesel liquid fuels within the range of -30 to 300°C, using a small scale closed cup tester.¹⁶ It should be noted that flash point values are a function of the operational procedures, design and condition of the apparatus used. Consequently, results obtained using different test methods may not provide valid correlations.
- 2.2.4 Selected crude oil samples were sent to Core Lab., Maxxam Analytical and AITF for determination of the flash point in accordance with ASTM D93 and ASTM D3828. Samples NATX310406, WFIX130629, NATX303425 and PROX44169 were split so that an approximately 65 mL portion was sent to AITF and the remaining portion (about 185 mL) was sent to Maxxam Analytical. The flash point results are summarized in Table 2. All of the samples gave corrected flash points that were significantly less than 23°C.¹⁷ Note that as mentioned previously, the different cut-off points reported by the 3 laboratories reflect the differences in apparatus and method used.

Table 2: Flash Point Results

Sample identification	Laboratory	Test method	Corrected flash point (°C) ^{Note 1}
NATX310533-A	Core Lab.	ASTM D93	<-5
NATX310533-B	Maxxam Analytical	ASTM D93	<-35
NATX310595-A	Core Lab.	ASTM D93	<-5
NATX310595-B	Maxxam Analytical	ASTM D93	<-35
NATX310406	Maxxam Analytical	ASTM D93	<-35
	AITF	ASTM D3828	<-30
WFIX130629	Maxxam Analytical	ASTM D93	<-35
	AITF	ASTM D3828	<-30
PROX44211	Maxxam Analytical	ASTM D93	<-35
NATX310425	Maxxam Analytical	ASTM D93	<-35
ACFX73452	Maxxam Analytical	ASTM D93	<-35
NATX310572	Maxxam Analytical	ASTM D93	<-35
NATX310487	Maxxam Analytical	ASTM D93	<-35
NATX303425	Maxxam Analytical	ASTM D93	<-35
	AITF	ASTM D3828	<-30
PROX 44169	Maxxam Analytical	ASTM D93	<-35
	AITF	ASTM D3828	<-30

Note 1: observed flash point corrected for ambient barometric pressure.

(reproducibility) using this method. (<http://www.astm.org/COMMIT/D07PrecisionBias2.pdf>, web site consulted on 21 January 2014)

¹⁶ ASTM D3828-12a Standard Test Methods for Flash Point by Small Scale Closed Cup Tester

¹⁷ A flash point less than 23°C is one of the criteria for classifying a flammable liquid as Packing Group II, see paragraph 3.1.1

2.3 Boiling Point Distribution

- 2.3.1 The ASTM D86 method (atmospheric distillation) is the basic test method for determining the boiling range characteristics of a petroleum product.¹⁸ In this method, a 100-mL sample is distilled in a laboratory batch distillation apparatus at ambient pressure and under prescribed conditions. In ASTM D86 distillation, the initial boiling point (IBP) is the corrected temperature reading at the instant the first drop of condensate falls from the lower end of the condenser tube.
- 2.3.2 The ASTM D7169 method covers the determination of the boiling point distribution and cut point intervals of crude oils and residues using high temperature gas chromatography.¹⁹ A gas chromatography apparatus is used to obtain a chromatogram of the sample (a plot of carbon signal versus retention time) and the boiling point distribution is calculated from this chromatogram after making appropriate corrections. The IBP is determined as the temperature corresponding to an accumulated 0.5% of eluted sample²⁰ after correcting for sample recovery.
- 2.3.3 The IBP and boiling point distribution of selected crude oil samples were determined by Core Lab., Maxxam Analytical and AITF in accordance with ASTM D86 and ASTM D7169. Table 3 summarizes the IBP results obtained on the crude oil samples. All of the samples tested using the ASTM D86 method gave IBPs ranging from 43.9 to 50.0°C. The ASTM D86 IBP results obtained by Core Lab. were in good agreement with those obtained by Maxxam Analytical (the difference was 2.0°C for sample NATX310533 and 4.5°C for sample NATX310595).
- 2.3.4 Table 4 summarizes the atmospheric distillation results obtained by Maxxam Analytical for the crude oil samples. The atmospheric distillation analysis is also presented as plots of temperature versus volume percent for the 9 samples collected from the occurrence train (Figure 2) and for the 2 samples collected from the comparison unit train in Farnham (Figure 3). All 11 samples gave very similar boiling point distributions.
- 2.3.5 There was some concern that the tank cars' lading might have been exposed to heat before the tank cars were pulled back to Nantes, thereby affecting the validity of test results. However, no sign of fire damage such as discolored or burned paint was noted on the tail end tank cars. In addition, no unusual variations were noted in the results obtained from the tail end tank car samples. These samples gave very similar results to those obtained from the comparison unit train, which was not exposed to fire (compare Figures 2 and 3).
- 2.3.6 The ASTM D7169 IBP results obtained for the NATX310406, WFIX130629, NATX303425 and PROX44169 samples were at least 10°C lower than those obtained using the ASTM D86 method (Table 3). Figure 4 displays the boiling point distributions obtained using the ASTM D7169 method. The 4 samples tested

¹⁸ ASTM D86-12 Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure

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

²⁰ Elution is the process by which the components of a sample are separated for analysis within the gas chromatography apparatus

using this method gave similar results. It was noted that the ASTM D7169 method gives slightly higher percent recovered values than the ASTM D86 method in the low boiling point portion of the plot which corresponds to the lighter hydrocarbons (compare Figures 2 and 4). As mentioned previously, the 2 methods have a different definition of IBP and use completely different equipment. Consequently, the temperature ranges covered and the precision are different. This likely explains the different results obtained for the light end portion of the samples.

Table 3: Initial Boiling Point Results

Sample identification	Laboratory	Test method	Initial boiling point (°C) ^{Note 1}
NATX310533-A	Core Lab.	ASTM D86	48.0
NATX310533-B	Maxxam Analytical	ASTM D86	46.0
NATX310595-A	Core Lab.	ASTM D86	50.0
NATX310595-B	Maxxam Analytical	ASTM D86	45.5
NATX310406	Maxxam Analytical	ASTM D86	46.2
	AITF	ASTM D7169	<36.1
WFIX130629	Maxxam Analytical	ASTM D86	46.7
	AITF	ASTM D7169	<36.1
PROX44211	Maxxam Analytical	ASTM D86	48.5
NATX310425	Maxxam Analytical	ASTM D86	44.7
ACFX73452	Maxxam Analytical	ASTM D86	48.5
NATX310572	Maxxam Analytical	ASTM D86	43.9
NATX310487	Maxxam Analytical	ASTM D86	46.3
NATX303425	Maxxam Analytical	ASTM D86	46.2
	AITF	ASTM D7169	<36.1
PROX44169	Maxxam Analytical	ASTM D86	46.3
	AITF	ASTM D7169	<36.1

Note 1: ASTM D86 results corrected to 101.3 kPa

Table 4: Summary of Atmospheric Distillation Results (ASTM D86)

Sample id.	Distillation residue (vol. %)	Distillation recovery (vol. %)	Distillation loss (vol. %)	Distillation naphta (vol. %)	Distillation kerosene (vol. %)
NATX310533-B	32.6	66.4	1.0	32.4	15.2
NATX310595-B	23.8	75.2	1.0	34.7	15.2
NATX310406	26.2	72.8	1.0	35.9	15.0
WFIX130629	32.9	66.1	1.0	32.1	15.0
PROX44211	23.1	75.9	1.0	34.1	15.2
NATX310425	34.3	64.7	1.0	31.2	14.8
ACFX73452	19.7	79.3	1.0	32.4	15.2
NATX310572	30.3	68.7	1.0	33.3	15.2
NATX310487	31.7	67.3	1.0	33.7	14.5
NATX303425	33.8	65.2	1.0	31.3	14.9
PROX44169	32.8	66.2	1.0	32.2	15.1

2.4 Density Analysis

2.4.1 The ASTM D5002 method covers the determination of the density and relative density of crude oils that can be handled as liquids at temperatures between 15 and 35°C.²¹ The density is defined as the mass per unit volume at a specified temperature. The relative density is the ratio of the density of a material to the density of water at a stated temperature. The API Gravity is a special function of the relative density at 15.56°C (60°F) and is calculated as follows:²²

$$\text{API Gravity} = \left(\frac{141.5}{\text{Relative density at } 60^{\circ}\text{F}} \right) - 131.5$$

2.4.2 Four representative crude oil samples were sent to Maxxam Analytical for density analysis. Samples were selected from the tank cars that had given the lowest and highest IBP results (NATX 310572 and PROX 44211 - refer to Table 3). Lower and upper samples were tested for each to verify if any density gradient was present.

2.4.3 The results indicate that the samples collected from tank cars NATX 310572 and PROX 44211 had similar density properties (Table 5). There was no significant difference between the upper and lower samples. This is consistent with the absence of stratification in the tank cars that was visually determined when samples were collected (see paragraph 2.1.4).

²¹ ASTM D5002-99(2010) Standard Test Method for Density and Relative Density of Crude Oils by Digital Density Analyzer

²² Significance of Tests for Petroleum Products, MNL 1, Seventh Edition, Ed. S. J. Rand, (ASTM International, 2003), page 52

Table 5: Density Analysis of Selected Crude Oil Samples

Sample identification	Density at 15°C (kg/m ³)	Relative density at 15°C	API Gravity
NATX310572-C-TOP	815.9	0.8166	41.8
NATX310572-C-BOT	816.5	0.8172	41.7
PROX44211-C-TOP	821.9	0.8226	40.5
PROX44211-C-BOT	821.8	0.8225	40.5

2.5 Reid Vapour Pressure

2.5.1 Vapour pressure of crude oils is an important physical property that affects general handling and refinery practices. It is also used as an indirect measure of the evaporation rate of volatile petroleum products. The ASTM D323 test method is used to determine the vapour pressure at 37.8°C (100°F) of petroleum products and crude oils with IBPs above 0°C (32°F).²³

2.5.2 The Reid vapour pressure of the 4 crude oil samples sent to Maxxam Analytical was determined in accordance with ASTM D323 Procedure A. The results indicate that samples collected from tank cars NATX 310572 and PROX 44211 had similar Reid vapour pressures ranging from 62.3 to 66.1 kPa (Table 6). There was no significant difference between the upper and lower samples.

Table 6: Reid Vapour Pressure (ASTM D323) and Total Sulphur Content (ASTM D4294) Results

Sample identification	Reid vapour pressure (kPa)	Total sulphur (mass %)
NATX310572-C-TOP	66.1	0.096
NATX310572-C-BOT	64.3	0.096
PROX44211-C-TOP	62.3	0.117
PROX44211-C-BOT	62.4	0.117

2.6 Sulphur Content

2.6.1 The sulphur content of crude oils affects their corrosiveness and toxicity. The ASTM D4294 test method covers the measurement of sulphur in hydrocarbons in the concentration range 0.0150 to 5.00 mass % sulphur.²⁴ The total sulphur content of the 4 samples sent to Maxxam Analytical was determined in accordance with ASTM D4294. The results indicate that the crude oil samples contained 0.096 to 0.117 mass % sulphur (Table 6). There was no difference between the upper and lower samples.

²³ ASTM D323-08 Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method)

²⁴ ASTM D4294-10 Standard Test Method for Sulphur in Petroleum and Petroleum Products by Energy Dispersive X-ray Fluorescence Spectrometry

2.7 Fluidity – Pour Point and Viscosity

- 2.7.1 Pour point and viscosity determinations are used mainly to determine the handling characteristics of crude oils at low temperatures. The fluidity properties are also indicative of the crude oil composition. For example, crude oils with a greater concentration of paraffinic compounds generally have a higher viscosity than crude oils having higher concentrations of aromatic and naphthenic compounds.²⁵
- 2.7.2 The ASTM D5853 method covers the determination of the pour point of crude oils.²⁶ A sample is cooled at a specified rate and examined at intervals of 3°C for flow characteristics. The pour point is the lowest temperature at which movement of the specimen is observed. Table 7 presents the pour point results obtained on the 4 samples sent to Maxxam Analytical. All of the samples gave pour points below -65°C.

Table 7: Pour Point (ASTM D5853) and Viscosity (ASTM D7042) Results

Sample identification	Pour point (°C)	Kinematic viscosity (mm ² /s) ^{Note 1}			
		Viscosity at 10°C	Viscosity at 20°C	Viscosity at 30°C	Viscosity at 40°C
NATX310572-C-TOP	<-65	3.639	2.882	2.295	1.910
NATX310572-C-BOT	<-65	3.720	2.982	2.467	2.080
PROX44211-C-TOP	<-65	4.100	3.259	2.665	2.230
PROX44211-C-BOT	<-65	4.078	3.220	2.548	2.205

Note 1: 1 mm²/s = 1 centistoke (cSt)

- 2.7.3 The ASTM D7042 test method specifies a procedure for concurrent measurement of the dynamic viscosity and density of liquid petroleum products and crude oils.²⁷ The dynamic viscosity is a measure of the resistance to flow of a liquid under external shear forces. The kinematic viscosity is a measure of the resistance to flow of the liquid under gravity. The kinematic viscosity is obtained by dividing the dynamic viscosity by the density obtained at the same temperature.
- 2.7.4 The kinematic viscosity of the 4 samples sent to Maxxam Analytical was determined using a Stabinger viscometer in accordance with ASTM D7042. The samples were tested at 20°C, 30°C and 40°C and these results were used to extrapolate the viscosity at 10°C. The results are summarized in Table 7. Slightly higher values were obtained at each temperature for the samples collected from the PROX 44211 tank car than for those collected from the NATX 310572 tank car. In the case of the NATX 310572 samples, the lower sample (NATX310572-C-BOT) gave slightly higher results at each temperature than the upper sample (NATX310572-C-TOP). This trend was reversed for the PROX 44211 samples.

²⁵ Significance of Tests for Petroleum Products, MNL 1, Seventh Edition, Ed. S. J. Rand, (ASTM International, 2003), page 54

²⁶ ASTM D5853-11 Standard Test Method for Pour Point of Crude Oils

²⁷ ASTM D7042-12a Standard Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)

2.8 Heat of Combustion

- 2.8.1 The ASTM D240 test method²⁸ covers the determination of the heat of combustion of liquid hydrocarbon fuels ranging in volatility from light distillates to that of residual fuels. The heat of combustion is a measure of the energy available from a given fuel. The gross heat of combustion is defined in ASTM D240 as the quantity of energy released when a unit mass of fuel is burned in a constant volume enclosure, with the products being gaseous, other than water that is condensed to the liquid state.
- 2.8.2 Table 8 summarizes the gross heat of combustion results obtained on the 4 crude oil samples sent to Maxxam Analytical. Similar results were obtained for the 4 samples, ranging from 18,445 to 19,416 Btu/lb²⁹ (42.905 to 45.160 MJ/kg). The upper samples (NATX310572-C-TOP and PROX44211-C-TOP) gave slightly higher values than the corresponding lower samples (NATX310572-C-BOT and PROX44211-C-BOT).

Table 8: Heat of Combustion (ASTM D240) Results

Sample identification	Gross heat of combustion	
	(Btu/lb)	(MJ/kg) ^{Note 1}
NATX310572-C-TOP	19,247	44.770
NATX310572-C-BOT	18,445	42.905
PROX44211-C-TOP	19,416	45.160
PROX44211-C-BOT	19,164	44.575

Note 1: 1 Btu/lb = 0.002326 MJ/kg

2.9 BTEX Compounds

- 2.9.1 BTEX is the acronym used for a group of volatile aromatic compounds (VOCs): benzene, toluene, ethylbenzene and the xylene isomers.^{30 31} The BTEX compounds occur naturally as constituents of crude oil. They are the most soluble and mobile fraction of crude oil and consequently, readily enter soil and ground water during accidental spills. These substances have toxic effects and are subject to occupational exposure limits. BTEX are classified as priority pollutants regulated by Environment Canada and the U.S. Environmental Protection Agency.
- 2.9.2 Aliquots (20 mL in volume) were taken from 4 selected crude oil samples and sent to the Cassen laboratory for BTEX analysis using a gas chromatography mass spectrometry (GC/MS) method.³² The results are summarized in Table 9.

²⁸ ASTM D240-09 Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter

²⁹ British thermal unit per pound

³⁰ An isomer is one of two or more compounds with the same number and type of atoms but different structure and properties

³¹ There are 3 forms of xylene in which the methyl groups vary on the benzene ring: meta-xylene (m-xylene), para-xylene (p-xylene) and ortho-xylene (o-xylene)

³² Cassen method M.3005.R0, reference method EPA 600/R-03/072, "Characteristics of Spilled Oils, Fuels, and Petroleum Products: 1. Composition and Properties of Selected Oils", July 2003

The benzene content measured in the 4 samples ranged from 1470 to 1850 ppm³³ (0.147 to 0.185%). Overall, the concentrations obtained for the BTEX compounds ranged from a lowest result of 768 ppm (0.0768%) for toluene to a highest result of 3500 ppm (0.35%) for m/p-xylene.³⁴

Table 9: BTEX Results

Analyte	CAS number ³⁵	Analytical results (ppm)			
		NATX310572-C-TOP	NATX310533-C-TOP	NATX310595-C-TOP	ACFX73452-C-TOP
Benzene	71-43-2	1850	1720	1800	1470
Toluene	108-88-3	3170	2870	2920	2770
Ethylbenzene	100-41-4	850	768	789	852
m/p-Xylene	106-42-3	3500	3300	3310	2890
o-Xylene	95-47-6	1660	1560	1620	1500

3.0 DISCUSSION

3.1 Classification of the Occurrence Crude Oil

3.1.1 According to the Transportation of Dangerous Goods (TDG) regulations³⁶ and the U.S. Code of Federal Regulations Title 49³⁷, liquids or liquids containing solids in solution or suspension are included in Class 3, Flammable Liquids, if they have a flash point less than or equal to 60°C using the closed-cup test method. Flammable liquids are further classified in one of three packing groups:

- Packing Group I, if they have an initial boiling point of 35°C or less at an absolute pressure of 101.3 kPa and any flash point;
- Packing Group II, if they have an initial boiling point greater than 35°C at an absolute pressure of 101.3 kPa and a flash point less than 23°C; or
- Packing Group III, if the criteria for inclusion in Packing Group I or II are not met.

3.1.2 The flash point results obtained for the subject crude oil samples were all significantly less than 23°C (Table 2) whereas the IBP results determined using the ASTM D86 method ranged from 43.9 to 50.0°C (Table 3). Consequently, all of these crude oil samples met the criteria for Class 3, Packing Group II.

3.2 Chemical and Physical Properties of the Occurrence Crude Oil

3.2.1 The chemical and physical test results obtained on the 9 occurrence crude oil samples show that there was little variation from tank car to tank car. Lower and upper samples gave similar results suggesting there was no significant stratification of the liquid phase within the tank cars.

³³ parts per million

³⁴ m-/p-xylene is the combined content of meta- and para-xylene

³⁵ The CAS (Chemical Abstracts Service) number is a unique identifier for a chemical substance. It has no inherent chemical significance but provides an unambiguous way to identify a chemical substance or molecular structure when there are many possible names in use

³⁶ Transportation of Dangerous Goods Regulations Part II, Class 3 Flammable Liquids, 2.18 General and 2.19 Packing Groups

³⁷ U. S. Code of Federal Regulations Title 49 Part 173.120 Class 3-Definitions and 173.121 Class 3-Assignment of packing group

- 3.2.2 Petroleum crude oil has been defined as “A complex combination of hydrocarbons. It consists predominantly of aliphatic, alicyclic and aromatic hydrocarbons. It may also contain small amounts of nitrogen, oxygen and sulphur compounds. This category encompasses light, medium, and heavy petroleums, as well as the oils extracted from tar sands.”³⁸ Crude oils are natural products and their chemical and physical properties can vary widely depending upon their origin and extraction method.
- 3.2.3 Conventional oil, which can range from light to medium in grade, is found in reservoir rocks with sufficient permeability to allow the oil to flow through the rock to a well. The petroleum crude oil on the occurrence train originated from suppliers with producing wells in the Bakken Shale formation region of North Dakota. The Bakken Shale formation is a tight oil reservoir. Tight oil is a type of conventional oil that is found within reservoirs with very low permeability. Most oil produced from low-permeability reservoirs is of the light to medium variety, with a lower viscosity. Advanced production technologies such as horizontal drilling coupled with multi-stage fracturing are required to extract the oil from these tight reservoirs.³⁹ The hydraulic fracturing process applies pressure by pumping fluids into the wellbore to open up pathways through which the oil can flow into the wellbore. Water is commonly used as the main constituent of the fracturing process fluid to which small amounts of different additives are added to reduce friction and to prevent corrosion and biofouling.⁴⁰
- 3.2.4 Table 10 compares the property results obtained for the occurrence crude oil samples with published values for petroleum products ranging from condensate to heavy crude oil. For simplicity, only the upper samples (NATX310572-C-TOP and PROX44211-C-TOP) are shown since similar results were obtained for upper and lower samples. The published values are taken from the 2013 Crude Characteristics Booklet⁴¹, which is a summary of selected chemical and physical properties of crude oils moved in the Enbridge Pipelines/Enbridge Energy Partners system.
- 3.2.5 The National Energy Board of Canada (NEB) defines “light crude oil” as oil having a density equal to, or less than, 875.7 kg/m³.⁴² The density of the occurrence crude oil samples ranged from 815.9 to 821.9 kg/m³, which meets the NEB definition for “light crude oil”. These density results were similar to the density reported for MST (Manitoba Sweet Tundra), a light crude oil product (Table 10). The vapour pressure and viscosity properties of the occurrence crude oil samples were also similar to those reported for MST. Heavy crude oils⁴³ have significantly lower vapour pressure, higher density and much higher viscosity than light crude oils - see for example the WCB product in Table 10.

³⁸ Toxic Substances Control Act Definition 2008, <http://chem.sis.nlm.nih.gov/chemidplus/rn/8002-05-9>, website consulted on 20 November 2013

³⁹ Understanding Tight Oils, Canadian Society for Unconventional Resources, http://www.csur.com/sites/default/files/Understanding_TightOil_FINAL.pdf, website consulted on 21 November 2013

⁴⁰ <http://fracfocus.org/water-protection/drilling-usage>, website consulted on 21 November 2013

⁴¹ <http://www.enbridge.com/DeliveringEnergy/Shippers/CrudeOilCharacteristics.aspx>, website consulted on 13 January 2014

⁴² National Energy Board Act Part VI (Oil and Gas) Regulations SOR/96-244, Section 2

⁴³ The NEB Regulations define “heavy crude oil” as oil with a density greater than 875.7 kg/m³

3.2.6 Condensates are mixtures of light hydrocarbons (with some dissolved hydrocarbon gases such as butane and propane) that remain liquid under modest pressures at ambient temperatures. Condensate products are recovered mainly from gas reservoirs and have significantly lower density and viscosity than other crude oils - see for example the CPM (Pembina Condensate) product in Table 10. Published analyses indicate that CPM contains about 80 vol% total C12- (hydrocarbons with 12 carbon atoms or less).⁴⁴ It is interesting to note that the occurrence crude oil samples and MST product have similar vapour pressure as CPM, suggesting that their volatility is similar to that of this condensate product. Flash points are not reported in the 2013 Crude Characteristics Booklet.

Table 10: Comparison of Occurrence and Published Crude Oil Properties

Source	Product identifier	Total sulphur (mass %)	Reid vapour pressure (kPa)	Density (kg/m ³)	Viscosity (cSt) at temperature			
					10°C	20°C	30°C	40°C
Occurrence test results	NATX310572-C-TOP	0.096	66.1	815.9	3.639	2.882	2.295	1.910
	PROX44211-C-TOP	0.117	62.3	821.9	4.100	3.259	2.665	2.230
2013 Crude Characteristics Booklet	CPM (Pembina Condensate)	0.10	70.6	757.4	1.21	1.07	0.960	0.860
	MST (Manitoba Sweet Tundra)	0.41	71.0	825.3	4.44	3.50	2.83	2.36
	WCB (Western Canadian Blend)	3.04	22.0	927.5	285	149	85.4	53.1

3.2.7 The Environmental Technology Centre (ETC) Oil Properties Database reports the following properties for unleaded gasoline:⁴⁵

- Flash point -30°C
- Density at 15°C 750 to 850 kg/m³
- Kinematic viscosity <1 cSt at 38°C

Comparing these values to the occurrence crude oil results summarized in Table 2, it is apparent that the occurrence crude oil's flash point is similar to that of unleaded gasoline. The density results obtained for the occurrence crude oil samples (see Table 10) are also within the range reported for unleaded gasoline. However, unleaded gasoline has lower viscosity than the occurrence crude oil samples.

3.3 Sulphur Content of the Occurrence Crude Oil

3.3.1 The Canadian Center for Energy defines "sweet" crude oil as oil containing less than 0.5 percent sulphur.⁴⁶ In the present case, sulphur analysis of representative occurrence crude oil samples gave total sulphur results ranging from 0.096 to 0.117 mass %, meeting the Canadian Center for Energy's definition for "sweet" crude oil. The total sulphur content of the occurrence crude oil is lower than that reported for the MST product and similar to the CPM product (Table 10). In

⁴⁴ <http://www.crudemonitor.ca/condensate.php?acr=CPM>, website consulted on 13 January 2014.

⁴⁵ [http://www.etc-cte.ec.gc.ca/databases/Oilproperties/pdf/WEB_Gasoline_\(Unleaded\).pdf](http://www.etc-cte.ec.gc.ca/databases/Oilproperties/pdf/WEB_Gasoline_(Unleaded).pdf), website consulted on 14 January 2014

⁴⁶ <http://www.centreforenergy.com/Glossary.asp?EnergyType=1&Template=1,1#83>, website consulted on 20 November 2013

comparison, the WCB product has significantly higher sulphur content, placing it in the “sour” crude category.

3.3.2 Hydrogen sulphide is a toxic gas that can be present as a dissolved compound in crude oil. It can also be evolved when sulphur compounds in the crude oil decompose during distillation or other heating processes. During an oil spill, the presence of hydrogen sulphide is a safety concern since it is extremely flammable and toxic.⁴⁷ In the present case, CTEH⁴⁸ monitored the derailment site during the TSB field investigation. No detectable levels of hydrogen sulphide were found. This is consistent with the low total sulphur content measured in the occurrence crude oil samples.

3.4 BTEX in the Occurrence Crude Oil

3.4.1 The occurrence crude oil’s BTEX content (Table 9) is comparable to typical values reported for crude oils.⁴⁹ Table 11 summarizes some of the exposure limits recommended for BTEX compounds. CTEH reported benzene and other VOC contents well above these exposure limits in portions of the derailment site that were extensively contaminated with the spilled crude oil.⁵⁰ This is consistent with the significant concentrations of benzene and other VOCs measured in the occurrence crude oil samples (Table 9).

Table 11: Recommended Exposure Limits for BTEX Compounds⁵¹

Substance	ACGIH® ⁵² TLV® ⁵³ (ppm)	Exposure guideline comments
Benzene	2.5	Short term exposure limit (15 min) Confirmed human carcinogen
Toluene	20	Time-weighted average (8 h) Not classifiable as human carcinogen
Ethylbenzene	20	Short term exposure limit (15 min) Possibly carcinogenic to humans
Xylene	100	Time-weighted average (8 h) Not classifiable as human carcinogen

⁴⁷ http://www.ccohs.ca/oshanswers/chemicals/chem_profiles/hydrogen_sulfide.html, website consulted on 20 November 2013

⁴⁸ Center for Toxicology and Environmental Health, L.L.C. (CTEH®) is a private company specialized in the provision of toxicology and human health consulting services.

⁴⁹ <http://www.etc-cte.ec.gc.ca/databases/oilproperties/Default.aspx>

⁵⁰ This portion of the derailment site, the so called “red zone”, was not accessible to the public in order to protect the site and prevent the public from any potential exposures.

⁵¹ Sources: CAREX Canada (http://www.carexcanada.ca/en/profiles_and_estimates/); Canadian Center for Occupational Health and Safety (http://www.ccohs.ca/oshanswers/chemicals/chem_profiles/), websites consulted on 20 November 2013

⁵² American Conference of Governmental Industrial Hygienists

⁵³ Threshold Limit Value

3.5 Effect of Crude Oil Properties on the Post-derailment Spill and Fire

3.5.1 Some of the properties that determine crude oil's behaviour and effects during an oil spill incident are:⁵⁴

- the extent to which the oil evaporates, which is related to its vapour pressure;
- the rate at which spilled oil spreads and the extent to which it penetrates the soil, which depends on its viscosity;
- density of the oil, which determines if it is likely to sink or float on water;
- health hazards to on-site personnel from volatile organic compounds and hydrogen sulphide (if present).

3.5.2 Overall, the occurrence crude oil gave low density, low total sulphur, low viscosity, low pour point and low flash point results, generally comparable with other light sweet crude oil products. A high vapour pressure was measured on the occurrence samples, similar to those reported for other light sweet crude oil and condensate products. The IBPs determined by the ASTM D7169 (gas chromatography) method were below 36°C, corresponding to the normal boiling point for pentane (C5).⁵⁵ This suggests there was some content of lighter hydrocarbons in the samples, consistent with their high vapour pressure results.

3.5.3 The low flash point, low IBP and high vapour pressure results obtained for the occurrence crude oil samples suggest that these samples contained some very light hydrocarbons. Given that the occurrence crude oil samples were taken at atmospheric pressure, this could lead to an underestimation of the volatility of the crude oil as the concentration of light hydrocarbons may have been higher at the time of loading, and later reduced due to evaporation losses.

3.5.4 TSB is unaware of any standard methods intended to sample and to quantify the liquefied and/or dissolved gas content of crude oil in tank cars. Although the ASTM D3700 standard practice covers the equipment and procedures for obtaining representative samples of single-phase liquefied petroleum gas (LPG),⁵⁶ this practice is not intended for non-specification products that contain significant amounts of dissolved gases, free water or other separated phases, such as raw or unprocessed gas/liquids mixtures and related materials. The same equipment could be used for this purpose but additional precautions would be needed to obtain representative samples.

3.5.5 The event tree for the release of crude oil from derailed tank cars can follow 2 pathways depending upon whether the release is accompanied or not by immediate ignition (Figure 5). Ignition is defined as the onset of combustion (flaming) and 3 conditions must be fulfilled for ignition to occur:⁵⁷

- the material must emanate sufficient quantities of vapours or gases;
- the vapours or gases must be mixed with a sufficient quantity of oxidant (oxygen in air);

⁵⁴ Properties of Crude Oils and Oil Products Database - Introduction, Environment Canada, <http://www.oilproduction.net/files/Introduction.pdf> (website consulted on 21 November 2013)

⁵⁵ Refer to ASTM D7169-11 Table 3 Boiling Points of Paraffins

⁵⁶ ASTM D3700-12 Standard Practice for Obtaining LPG Samples Using a Floating Piston Cylinder

⁵⁷ SPFE Handbook of Fire Protection Engineering, 4th Edition (National Fire Protection Association, 2008), Chapter 2-8 Ignition of Liquids

- the air-vapour mixture must be at a temperature high enough to auto-ignite (self-accelerative oxidation) or a source of ignition (a spark, small flame or other localized source of heat) must be provided.
- 3.5.6 In the present case, a large number of tank cars sustained large ruptures during the derailment and released their content very rapidly. The spilled crude oil had high vapour pressure and a low flash point ($< -35^{\circ}\text{C}$) that was much lower than the temperature at the time of the occurrence (21°C), indicating it was readily ignitable. Multiple sources of ignition were present at the derailment site such as damaged power lines, derailed equipment, etc. Therefore, all of the conditions required for ignition to occur were present. When the release is a large spill accompanied by immediate ignition (left branch on Figure 5), the result is usually a fireball. The size of this fireball will depend strongly on the amount of flash vaporization and liquid entrainment that occur during the release.⁵⁸ This suggests that more volatile materials (with higher vapour pressure) and high speed derailments (with more energetic impacts and release of lading) will result in larger fireballs. Spilled material that does not ignite immediately (right branch on Figure 5) will spread and accumulate into a pool. The size of this pool will continue to increase until a physical boundary is reached or the material is ignited and burns, resulting in a pool fire.
- 3.5.7 The viscosity of the occurrence crude oil was similar to that of other light sweet crude oil products; hence it would be expected to have similar spreading characteristics during a spill. The occurrence crude oil's low viscosity was likely contributory to the rapid spread of the spill and flow of crude oil through the town towards the lake. The occurrence crude oil was very volatile, as indicated by its low flash point and high vapour pressure. To summarize, it is considered that the large quantities of spilled crude oil, the rapid rate of release and the oil's high volatility and low viscosity were likely the major contributors to the large fireball and pool fire.
- 3.5.8 The heat of combustion (also called heating value) is a measure of the total amount of energy that can be released when a fuel is burned to completion. Table 12 compares the gross heat of combustion obtained for the occurrence crude oil samples with values reported in the available literature for other types of fuels.⁵⁹ The results obtained for the occurrence crude oil samples are similar to those reported for crude oil, gasoline and diesel fuels, indicating that all of these fuels will release similar amounts of energy under ideal conditions where fuel is burned to completion. However, it is known that this is never the case in real fires. Even under conditions of unrestricted ventilation (in open air), the combustion products contain compounds that are only partially oxidized such as carbon monoxide, aldehydes, ketones and soot (carbon) particles, indicating that not all of the available energy has been released.⁶⁰

⁵⁸ Ibid, Chapter 3-10 Fire Hazard Calculations for Large, Open Hydrocarbon Fires

⁵⁹ Biomass Energy Data Book, Edition 4, Appendix A (U.S. Department of Energy, 2011), <http://cta.ornl.gov/bedb>, website consulted on 14 January 2014

⁶⁰ SPFE Handbook of Fire Protection Engineering, 4th Edition (National Fire Protection Association, 2008), Chapter 5-1 Thermochemistry

Table 12: Heat of Combustion of Selected Liquid Fuels

Product	Heat of combustion (MJ/kg)	Density (kg/m ³)	Reference
Occurrence crude oil samples	42.905 to 45.160	815.9 to 821.9	Table 8
Crude oil	45.543	821.8	Biomass Energy Data Book
Conventional gasoline	46.536	722.8	
Conventional diesel	45.766	812.1	
Ethanol	29.847	766.2	
Liquefied petroleum gas	50.152	493.1	

3.5.9 The thermal radiation hazards from hydrocarbon pool fires are known to depend on parameters such as the hydrocarbon composition, size and shape of the pool, duration of the fire and the proximity and thermal characteristics of objects exposed to the fire.⁶¹ Semi-empirical methods are used to estimate the thermal radiation field surrounding a fire. The estimation of the thermal radiation field surrounding the occurrence fire is beyond the scope of the present report. However, temperatures within pool fires have been reported in the available literature. Over a wide range of pool sizes (0.1 to 50 m in diameter), the maximum time-averaged flame temperatures were found to be approximately 900 to 1100°C, irrespective of the type of fuel.⁶²

4.0 CONCLUSION

- 4.1 The flash point obtained for the occurrence crude oil samples was significantly less than 23°C and the IBP determined using the ASTM D86 method ranged from 43.9 to 50.0°C. Consequently, the crude oil samples clearly met the federal regulatory criteria for being classified as a flammable liquid of Class 3, Packing Group II.
- 4.2 The occurrence crude oil samples gave low density (815.9 to 821.9 kg/m³), low total sulphur (0.096 to 0.117 mass %), low viscosity (2.882 to 3.259 cSt at 20°C), low pour point (<-65°C), low flash point (<-35°C) and high Reid vapour pressure (62.3 to 66.1kPa) results.
- 4.3 The occurrence crude oil's properties were consistent with those of a light sweet crude oil, with volatility comparable to that of a condensate or gasoline product.
- 4.4 There was no indication that the occurrence crude oil's properties had been affected by contamination from fracturing process fluid additives.
- 4.5 The occurrence crude oil samples were taken at atmospheric pressure. This could lead to an underestimation of the crude oil's volatility due to evaporation loss of very light constituents.

⁶¹ Ibid, Chapter 3-10 Fire Hazard Calculations for Large, Open Hydrocarbon Fires

⁶² Ibid, page 3-295

- 4.6 The large quantities of spilled crude oil, the rapid rate of release, and the oil's high volatility and low viscosity were likely the major contributors to the large post-derailment fireball and pool fire.
- 4.7 The occurrence crude oil contained concentrations of BTEX that were comparable to typical values reported for crude oils. This explains why concentrations of benzene and other VOCs well above exposure limits were detected at the derailment site.



Figure 1: Photograph showing 2 representative occurrence crude oil samples (NATX310406-C-BOT and NATX310406-C-TOP)

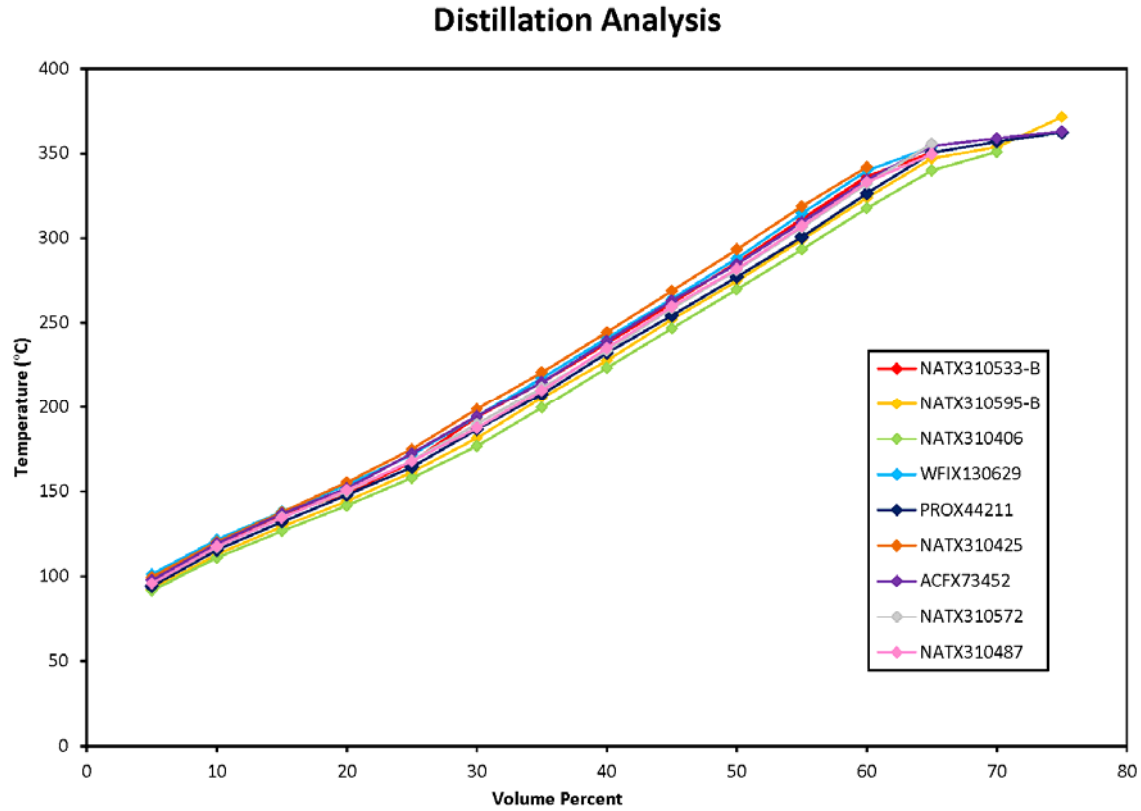


Figure 2: Atmospheric distillation plots (ASTM D86) for 9 crude oil samples taken from the occurrence train MMA-002

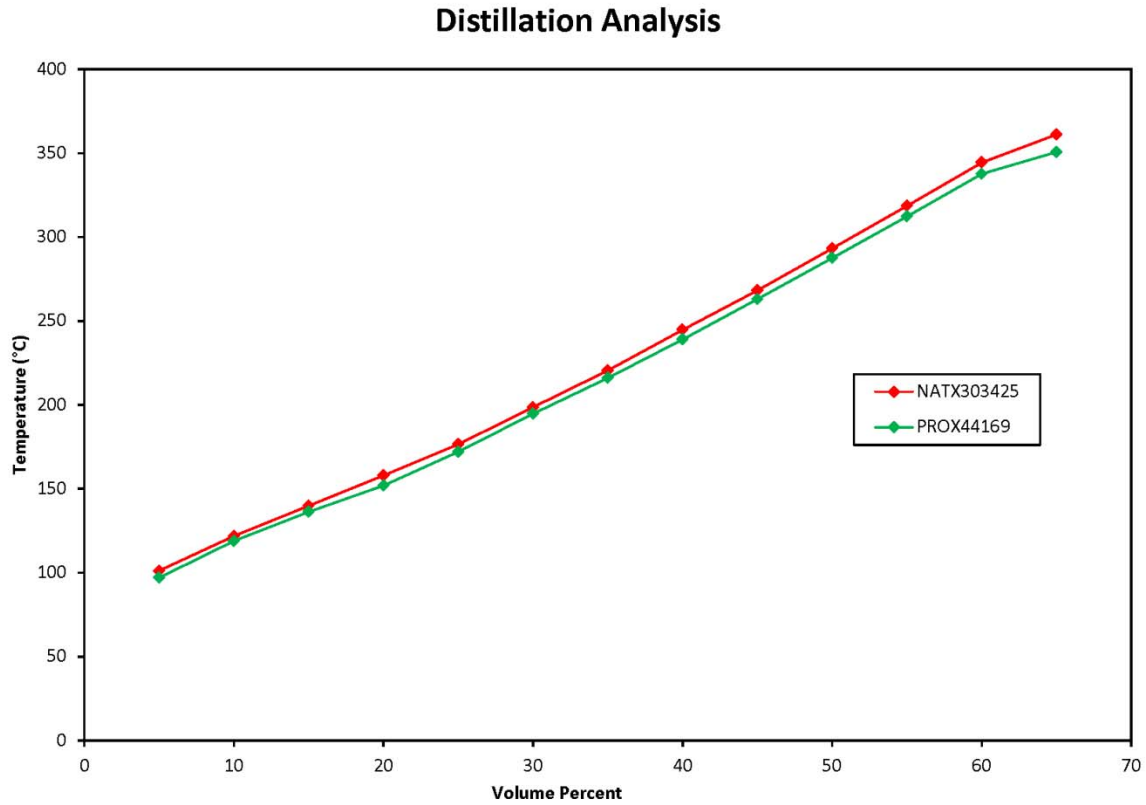


Figure 3: Atmospheric distillation plots (ASTM D86) for 2 crude oil samples taken from the unit train MMA-874 located at Farnham, Quebec

Boiling Point Distribution

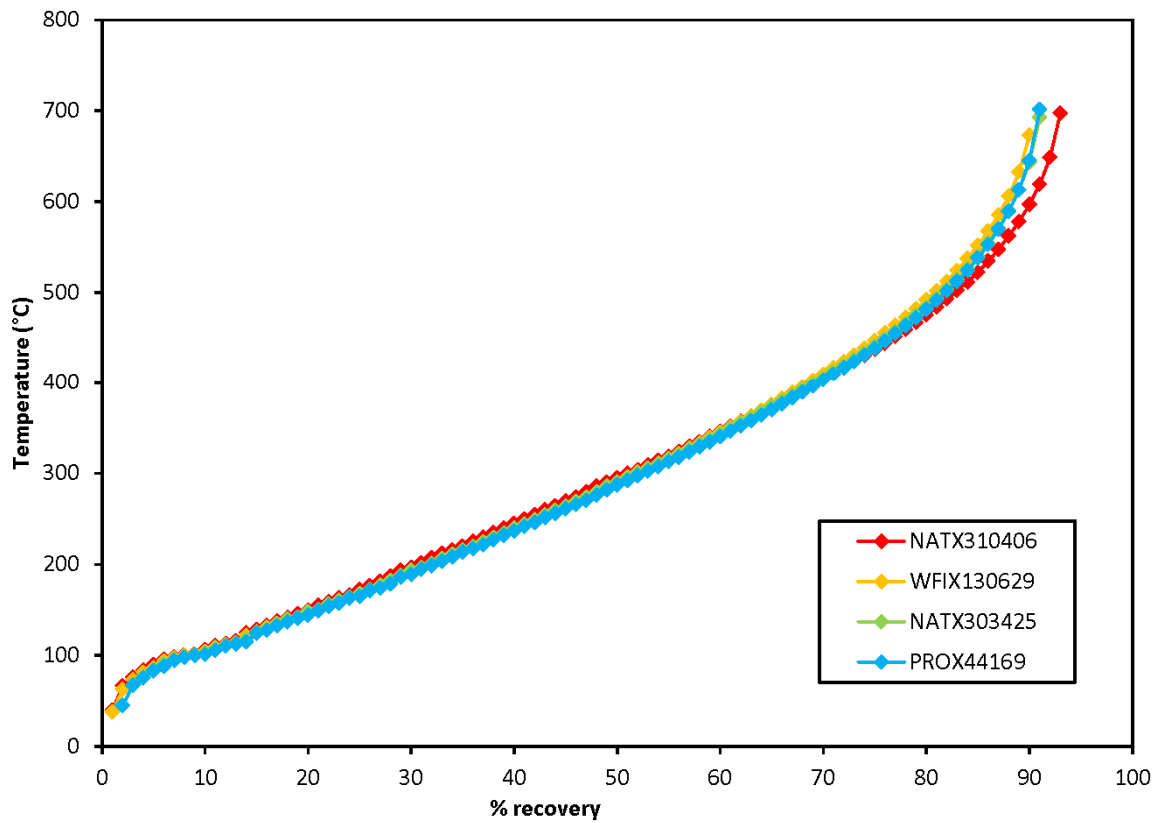


Figure 4: Boiling point distribution (ASTM D7169) for 4 crude oil samples taken from the occurrence train MMA-002

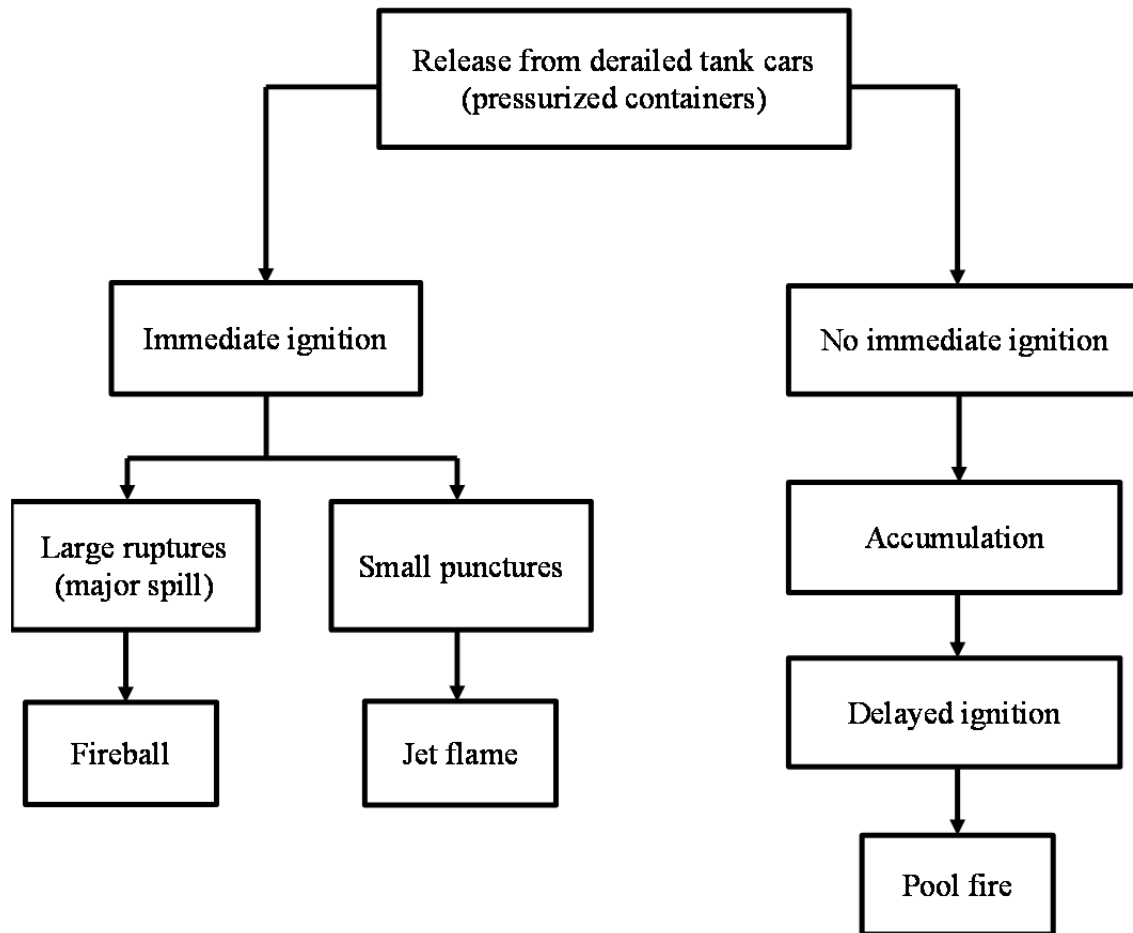


Figure 5: Event tree for release of crude oil from derailed tank cars ⁶³

⁶³ Adapted from SPFE Handbook of Fire Protection Engineering, 4th Edition (National Fire Protection Association, 2008), Figure 3-10.1, page 3-272

Appendix A: Analytical Reports Provided by External Laboratories

Note: Analytical Reports Provided by External Laboratories are only provided in English – the language in which they were prepared.



LABORATORY TEST RESULTS

FILE NUMBER: 52137-2013-2615

COMPANY: Transportation Safety Board of Canada

SAMPLE NAME: NATX 310533 A
 DATE SAMPLED: 26-Jul-13
 SAMPLE DESCRIPTION: Oil

LABORATORY I.D.: 52137-2013-2615-1-342
 DATE RECEIVED: 30-Jul-13

TEST DESCRIPTION	RESULTS	UNIT OF MEASURE	TEST METHOD	DATE ANALYZED	TECH
Pensky-Martens Flash Point	< -5	°C	ASTM D-93	30-Jul-13	JC
Atmospheric Distillation		°C (AET Corrected)	ASTM D-86	30-Jul-13	SP
Initial Boiling Point	48.0				
5 % Off	82.0				
10 % Off	101.5				
15 % Off	118.0				
20 % Off	134.0				
25 % Off	150.0				
30 % Off	168.0				
35 % Off	186.5				
40 % Off	204.5				
45 % Off	231.5				
50 % Off	253.0				
55 % Off	274.0				
60 % Off	297.0				
65 % Off	327.5				
70 % Off	351.5				
75 % Off	367.5				
80 % Off	369.5				
85 % Off	372.5				
90 % Off	375.5				
Crack Point	376.5				
Final Boiling Point	376.5				
Percent Recovery	94				
Percent Residue	6				
Percent Loss	0				

CORE LABORATORIES
 2810 - 12th Street N.E.
 CALGARY, ALBERTA T2E 7P7



LABORATORY TEST RESULTS

FILE NUMBER: 52137-2013-2615

COMPANY: Transportation Safety Board of Canada

SAMPLE NAME: NATX 310595 A
 DATE SAMPLED: 26-Jul-13
 SAMPLE DESCRIPTION: Oil

LABORATORY I.D.: 52137-2013-2615-2-343
 DATE RECEIVED: 30-Jul-13

TEST DESCRIPTION	RESULTS	UNIT OF MEASURE	TEST METHOD	DATE ANALYZED	TECH
Pensky-Martens Flash Point	< -5	°C	ASTM D-93	30-Jul-13	JC
Atmospheric Distillation		°C (AET Corrected)	ASTM D-86	30-Jul-13	SP
Initial Boiling Point	50.0				
5 % Off	85.5				
10 % Off	105.5				
15 % Off	122.5				
20 % Off	138.0				
25 % Off	154.0				
30 % Off	175.0				
35 % Off	196.5				
40 % Off	217.0				
45 % Off	240.5				
50 % Off	261.5				
55 % Off	286.0				
60 % Off	314.5				
65 % Off	343.5				
70 % Off	361.5				
75 % Off	366.5				
80 % Off	369.5				
85 % Off	373.5				
90 % Off	375.5				
Crack Point	375.5				
Final Boiling Point	375.5				
Percent Recovery	93				
Percent Residue	7				
Percent Loss	0				

CORE LABORATORIES
 2810 - 12th Street N.E.
 CALGARY, ALBERTA T2E 7P7

Report of Analysis

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Reported: 25-Sep-2013
Revision: 2013-1

Report To:

Transportation Safety Board of Canada
1901 Research Road
Ottawa, Ontario, K1A 1K8

Attention: Dr. Sylvie Dionne
E-mail: sylvie.dionne@tsb-bst.gc.ca
Fax: 613- 998-5572

Invoice To:

Transportation Safety Board of Canada
1901 Research Road
Ottawa, Ontario K1A 1K8

Attention: Dr. Sylvie Dionne
E-mail:
Fax:

Order Id: FL13_1205
Contract #:
Contract Name:
PO#:

Lab Sample Number	Client's Reference Matrix; Date Received	Test	Method	Analysis Parameter	Result	Notes
FL13_1205-001	TSB CAR 1 Crude Oil; 02-Aug-2013	ASTM D3828	Method B	Corrected Flash Point	<-30.0 °C	1
		ASTM D7169		Simulated Distillation	See Attached	
FL13_1205-002	TSB CAR 2 Crude Oil; 02-Aug-2013	ASTM D3828	Method B	Corrected Flash Point	<-30.0 °C	1
		ASTM D7169		Simulated Distillation	See Attached	
FL13_1205-003	TSB CAR 3 Crude Oil; 02-Aug-2013	ASTM D3828	Method B	Corrected Flash Point	<-30.0 °C	1
		ASTM D7169		Simulated Distillation	See Attached	
FL13_1205-004	TSB CAR 4 Crude Oil; 02-Aug-2013	ASTM D3828	Method B	Corrected Flash Point	<-30.0 °C	1
		ASTM D7169		Simulated Distillation	See Attached	

Results relate only to items tested.

Report of Analysis

This report may only be reproduced in its entirety

Reported: 25-Sep-2013
Revision: 2013-1

Report To:

Transportation Safety Board of Canada
1901 Research Road
Ottawa, Ontario, K1A 1K8

Attention: Dr. Sylvie Dionne
E-mail: sylvie.dionne@tsb-bst.gc.ca
Fax: 613- 998-5572

Invoice To:

Transportation Safety Board of Canada
1901 Research Road
Ottawa, Ontario K1A 1K8

Attention: Dr. Sylvie Dionne
E-mail:
Fax:

Order Id: FL13_1205


Contract #:
Contract Name:
PO#:

Lab Sample Number	Client's Reference Matrix; Date Received	Test	Method	Analysis Parameter	Result	Notes
-------------------	------------------------------------------	------	--------	--------------------	--------	-------

Remarks and Notes

- The containers for samples TSB CAR 1 and TSB CAR 3 were leaking upon arrival.

Results relate only to items tested.

Approved by: 
 Susan Brown
 Specification Analytical Coordinator

Contact Information
 Portfolio Manager: Dan Wispinski
 Phone: (780) 450-5108
 Email: dan.wispinski@albertainnovates.ca

File: O:\SimDData\HPChem\1\data\FL13-1205F 2013-09-20 17-07-04\FL13-1205-001.D\FL13-1205-001_FID1_A.CDF Sep-13, 07:02:34
 Sample: FL13-1205-001 Operator:
 Parameter: HTSD7169

Boiling Point Table (%Off)

ASTM D7169

Carbon (0) Channel

<u>%Off</u>	<u>BP(C)</u>	<u>%Off</u>	<u>BP(C)</u>	<u>%Off</u>	<u>BP(C)</u>
IBP	< 36.1	39.00	234.8	77.00	444.2
2.00	39.4	40.00	239.9	78.00	451.5
3.00	66.5	41.00	245.0	79.00	459.2
4.00	75.8	42.00	249.7	80.00	467.2
5.00	83.8	43.00	254.3	81.00	475.2
6.00	89.6	44.00	259.6	82.00	483.7
7.00	95.3	45.00	264.3	83.00	492.8
8.00	98.4	46.00	269.3	84.00	502.0
9.00	100.4	47.00	273.9	85.00	511.6
10.00	101.6	48.00	279.8	86.00	522.1
11.00	105.9	49.00	285.8	87.00	534.5
12.00	110.6	50.00	290.1	88.00	547.3
13.00	113.0	51.00	295.0	89.00	562.2
14.00	115.8	52.00	300.1	90.00	578.0
15.00	125.0	53.00	303.8	91.00	596.8
16.00	128.2	54.00	309.0	92.00	619.1
17.00	132.8	55.00	314.4	93.00	648.5
18.00	137.6	56.00	318.4	94.00	697.3
19.00	141.4	57.00	324.0		
20.00	145.4	58.00	329.6		
21.00	149.7	59.00	334.7		
22.00	155.0	60.00	340.7		
23.00	158.5	61.00	345.9		
24.00	163.4	62.00	351.7		
25.00	166.4	63.00	357.1		
26.00	172.1	64.00	363.1		
27.00	176.7	65.00	368.8		
28.00	181.3	66.00	374.8		
29.00	187.2	67.00	380.8		
30.00	193.2	68.00	387.0		
31.00	196.9	69.00	393.1		
32.00	201.6	70.00	399.6		
33.00	207.3	71.00	405.6		
34.00	212.1	72.00	412.0		
35.00	215.8	73.00	418.0		
36.00	220.0	74.00	424.1		
37.00	225.3	75.00	430.6		
38.00	230.0	76.00	437.2		

Recovery: 94.15 @707.8C
Analysis Area: 1.08194e-01
Detector RF: 5.68108e-08
R.Time Date: 9/23/2013

Start Time: 0.098 min.
Start Signal: 0.000 pA
Sample Amt: 0.2053
R.Factor Date: 9/23/2013

End Time: 28.558 min.
End Signal: 0.000 pA
Solvent Amt: 12.5472

Response Factor: 1.40081e-01
R.Time File: O:\SimDData\HPChem\1\data\FL13-1205F 2013-09-20 17-07-04\RT-INITR.D\RT-INITR_FID1_A.CDF
R.Factor File: O:\SimDData\HPChem\1\data\FL13-1205F 2013-09-20 17-07-04\RF-INIT.D\RF-INIT_FID1_A.CDF
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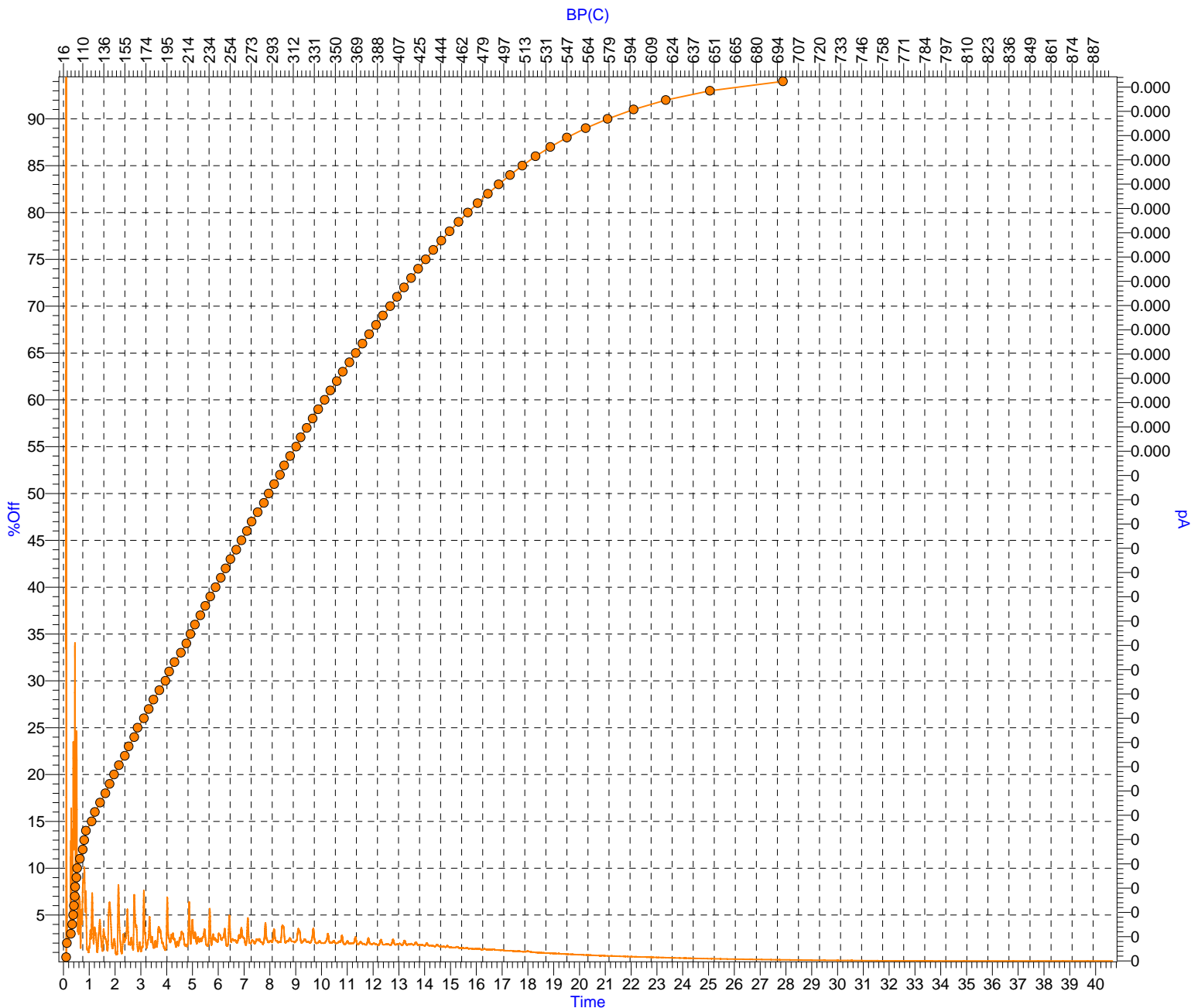
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 Sample: FL13-1205-001
 Parameter: HTSD7169

Sep-13, 07:02:34
 Operator:

Distillation Chart

ASTM D7169

Carbon (0) Channel



Recovery: 94.15 @707.8C
Analysis Area: 1.08194e-01
Detector RF: 5.68108e-08
R.Time Date: 9/23/2013

Start Time: 0.098 min.
Start Signal: 0.000 pA
Sample Amt: 0.2053
R.Factor Date: 9/23/2013

End Time: 28.558 min.
End Signal: 0.000 pA
Solvent Amt: 12.5472

Response Factor: 1.40081e-01
R.Time File: O:\SimDData\HPChem\1\data\FL13-1205F 2013-09-20 17-07-04\RT-INITR.D\RT-INITR_FID1_A.CDF
R.Factor File: O:\SimDData\HPChem\1\data\FL13-1205F 2013-09-20 17-07-04\RF-INIT.D\RF-INIT_FID1_A.CDF
Blank File: O:\SimDData\HPChem\1\data\FL13-1205F 2013-09-20 17-07-04\BLANK3B.D\BLANK3B_FID1_A.CDF

File: O:\SimDData\HPChem\1\data\FL13-1205F 2013-09-20 17-07-04\FL13-1205-002.D\FL13-1205-002_FID1_A.CDF Sep-13, 10:02:04
 Sample: FL13-1205-002 Operator:
 Parameter: HTSD7169

Boiling Point Table (%Off)

ASTM D7169

Carbon (0) Channel

<u>%Off</u>	<u>BP(C)</u>	<u>%Off</u>	<u>BP(C)</u>	<u>%Off</u>	<u>BP(C)</u>
IBP	< 36.1	39.00	229.4	77.00	455.2
2.00	37.9	40.00	234.4	78.00	463.9
3.00	62.7	41.00	239.4	79.00	472.7
4.00	73.1	42.00	244.2	80.00	481.8
5.00	81.4	43.00	249.0	81.00	491.8
6.00	86.5	44.00	253.9	82.00	501.8
7.00	93.5	45.00	259.3	83.00	512.2
8.00	97.0	46.00	264.0	84.00	524.1
9.00	99.8	47.00	269.0	85.00	537.3
10.00	100.7	48.00	273.9	86.00	551.5
11.00	104.3	49.00	279.8	87.00	567.5
12.00	108.8	50.00	285.9	88.00	585.2
13.00	111.6	51.00	290.6	89.00	606.1
14.00	113.9	52.00	295.6	90.00	632.8
15.00	122.1	53.00	301.2	91.00	673.2
16.00	125.9	54.00	305.7		
17.00	130.6	55.00	311.1		
18.00	135.3	56.00	316.2		
19.00	140.0	57.00	321.8		
20.00	141.9	58.00	327.7		
21.00	148.5	59.00	332.8		
22.00	150.3	60.00	339.0		
23.00	156.3	61.00	344.8		
24.00	160.1	62.00	350.7		
25.00	163.6	63.00	356.6		
26.00	167.3	64.00	363.0		
27.00	172.1	65.00	369.1		
28.00	176.7	66.00	375.7		
29.00	181.4	67.00	382.1		
30.00	187.0	68.00	389.0		
31.00	192.1	69.00	395.7		
32.00	196.2	70.00	402.5		
33.00	200.8	71.00	409.6		
34.00	206.4	72.00	416.6		
35.00	210.8	73.00	423.6		
36.00	215.1	74.00	431.0		
37.00	219.3	75.00	438.7		
38.00	224.5	76.00	446.8		

Recovery: 91.52 @707.8C
Analysis Area: 1.02733e-01
Detector RF: 5.68108e-08
R.Time Date: 9/23/2013

Start Time: 0.099 min.
Start Signal: 0.000 pA
Sample Amt: 0.2033
R.Factor Date: 9/23/2013

End Time: 28.558 min.
End Signal: 0.000 pA
Solvent Amt: 12.7227

Response Factor: 1.40081e-01
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Blank File: O:\SimDData\HPChem\1\data\FL13-1205F 2013-09-20 17-07-04\BLANK4B.D\BLANK4B_FID1_A.CDF

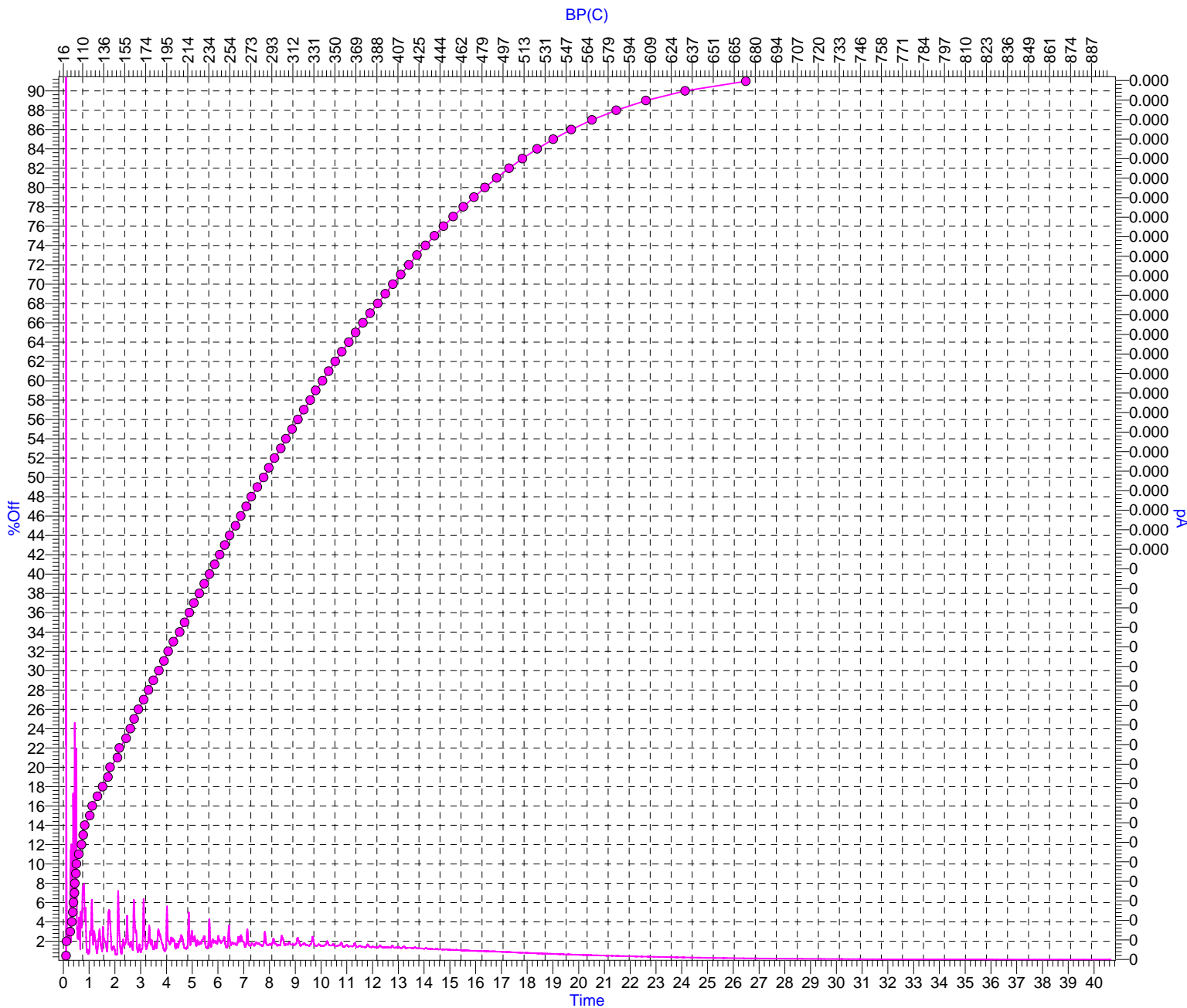
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 Sample: FL13-1205-002
 Parameter: HTSD7169

Sep-13, 10:02:04
 Operator:

Distillation Chart

ASTM D7169

Carbon (0) Channel



Recovery: 91.52 @707.8C
Analysis Area: 1.02733e-01
Detector RF: 5.68108e-08
R.Time Date: 9/23/2013

Start Time: 0.099 min.
Start Signal: 0.000 pA
Sample Amt: 0.2033
R.Factor Date: 9/23/2013

End Time: 28.558 min.
End Signal: 0.000 pA
Solvent Amt: 12.7227

Response Factor: 1.40081e-01
R.Time File: O:\SimDDData\HPChem\1\data\FL13-1205F 2013-09-20 17-07-04\RT-INITR.D\RT-INITR_FID1_A.CDF
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Blank File: O:\SimDDData\HPChem\1\data\FL13-1205F 2013-09-20 17-07-04\BLANK4B.D\BLANK4B_FID1_A.CDF

File: O:\SimDData\HPChem\1\data\FL13-1205F 2013-09-20 17-07-04\FL13-1205-003.D\FL13-1205-003_FID1_A.CDF
Sample: FL13-1205-003
Parameter: HTSD7169

Sep-13, 13:01:55
Operator:

Boiling Point Table (%Off)

ASTM D7169
Carbon (0) Channel

<u>%Off</u>	<u>BP(C)</u>	<u>%Off</u>	<u>BP(C)</u>	<u>%Off</u>	<u>BP(C)</u>
IBP	< 36.1	40.00	234.5	78.00	457.3
3.00	45.3	41.00	239.7	79.00	466.0
4.00	67.7	42.00	244.3	80.00	474.5
5.00	77.2	43.00	249.1	81.00	483.6
6.00	83.8	44.00	254.0	82.00	493.6
7.00	90.5	45.00	259.4	83.00	503.5
8.00	95.3	46.00	264.0	84.00	514.2
9.00	98.9	47.00	268.9	85.00	526.2
10.00	100.4	48.00	273.9	86.00	539.5
11.00	102.5	49.00	279.6	87.00	554.4
12.00	107.5	50.00	285.6	88.00	570.7
13.00	110.9	51.00	290.3	89.00	589.8
14.00	113.2	52.00	295.3	90.00	612.7
15.00	118.1	53.00	300.8	91.00	643.0
16.00	125.5	54.00	305.4	92.00	692.8
17.00	129.3	55.00	310.6		
18.00	134.4	56.00	315.8		
19.00	139.7	57.00	321.1		
20.00	141.8	58.00	326.8		
21.00	148.4	59.00	331.8		
22.00	150.4	60.00	337.8		
23.00	156.4	61.00	343.6		
24.00	160.4	62.00	349.2		
25.00	163.7	63.00	355.2		
26.00	168.0	64.00	361.1		
27.00	172.3	65.00	367.2		
28.00	177.1	66.00	373.3		
29.00	182.5	67.00	379.7		
30.00	187.4	68.00	386.0		
31.00	193.2	69.00	392.6		
32.00	196.6	70.00	399.3		
33.00	201.1	71.00	405.9		
34.00	206.6	72.00	412.7		
35.00	211.3	73.00	419.4		
36.00	215.3	74.00	426.4		
37.00	219.7	75.00	433.6		
38.00	224.7	76.00	441.2		
39.00	229.6	77.00	449.1		

Recovery: 92.36 @720.0C
Analysis Area: 1.16473e-01
Detector RF: 5.68108e-08
R.Time Date: 9/23/2013

Start Time: 0.098 min.
Start Signal: 0.000 pA
Sample Amt: 0.2302
R.Factor Date: 9/23/2013

End Time: 29.304 min.
End Signal: 0.000 pA
Solvent Amt: 12.8022

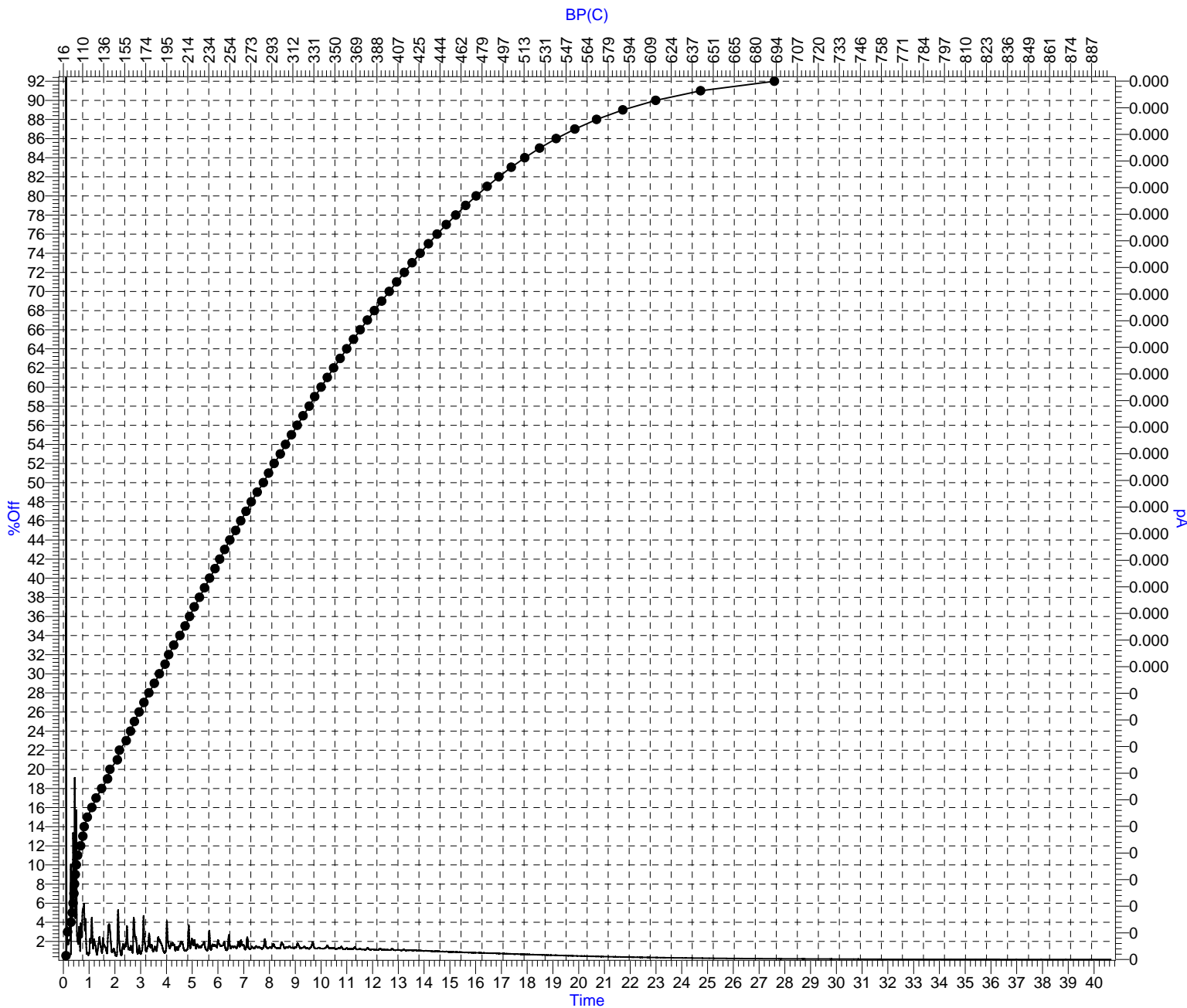
Response Factor: 1.40081e-01
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R.Factor File: O:\SimDData\HPChem\1\data\FL13-1205F 2013-09-20 17-07-04\RF-INIT.D\RF-INIT_FID1_A.CDF
Blank File: O:\SimDData\HPChem\1\data\FL13-1205F 2013-09-20 17-07-04\BLANK5B.D\BLANK5B_FID1_A.CDF

File: O:\SimDData\HPChem\1\data\FL13-1205F 2013-09-20 17-07-04\FL13-1205-003.D\FL13-1205-003_FID1_A.CDF
 Sample: FL13-1205-003
 Parameter: HTSD7169

Distillation Chart

ASTM D7169

Carbon (0) Channel



Recovery: 92.36 @720.0C
Analysis Area: 1.16473e-01
Detector RF: 5.68108e-08
R.Time Date: 9/23/2013

Start Time: 0.098 min.
Start Signal: 0.000 pA
Sample Amt: 0.2302
R.Factor Date: 9/23/2013

End Time: 29.304 min.
End Signal: 0.000 pA
Solvent Amt: 12.8022

Response Factor: 1.40081e-01
R.Time File: O:\SimDData\HPChem\1\data\FL13-1205F 2013-09-20 17-07-04\RT-INITR.D\RT-INITR_FID1_A.CDF
R.Factor File: O:\SimDData\HPChem\1\data\FL13-1205F 2013-09-20 17-07-04\RF-INIT.D\RF-INIT_FID1_A.CDF
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 Sample: FL13-1205-004 Operator:
 Parameter: HTSD7169

Boiling Point Table (%Off)

ASTM D7169

Carbon (0) Channel

<u>%Off</u>	<u>BP(C)</u>	<u>%Off</u>	<u>BP(C)</u>	<u>%Off</u>	<u>BP(C)</u>
IBP	< 36.1	40.00	231.7	78.00	454.7
3.00	44.9	41.00	236.4	79.00	463.3
4.00	67.0	42.00	241.4	80.00	472.1
5.00	75.0	43.00	246.1	81.00	481.2
6.00	83.0	44.00	251.4	82.00	491.2
7.00	88.1	45.00	255.9	83.00	501.4
8.00	94.3	46.00	261.2	84.00	512.0
9.00	97.6	47.00	265.4	85.00	524.1
10.00	100.0	48.00	270.1	86.00	537.7
11.00	100.9	49.00	275.9	87.00	552.7
12.00	105.4	50.00	281.6	88.00	569.6
13.00	110.0	51.00	287.1	89.00	589.2
14.00	112.3	52.00	292.3	90.00	613.0
15.00	115.0	53.00	297.2	91.00	645.4
16.00	124.2	54.00	302.3	92.00	701.4
17.00	127.5	55.00	307.4		
18.00	132.4	56.00	312.7		
19.00	136.9	57.00	317.5		
20.00	140.8	58.00	323.2		
21.00	144.0	59.00	329.0		
22.00	149.1	60.00	334.3		
23.00	153.7	61.00	340.4		
24.00	157.4	62.00	346.0		
25.00	162.8	63.00	351.9		
26.00	164.8	64.00	357.7		
27.00	171.2	65.00	363.9		
28.00	173.6	66.00	370.0		
29.00	178.5	67.00	376.4		
30.00	185.0	68.00	382.9		
31.00	188.8	69.00	389.6		
32.00	194.7	70.00	396.2		
33.00	198.5	71.00	402.9		
34.00	203.2	72.00	409.8		
35.00	208.0	73.00	416.7		
36.00	213.6	74.00	423.6		
37.00	216.9	75.00	430.8		
38.00	221.2	76.00	438.4		
39.00	226.6	77.00	446.4		

Recovery: 92.09 @707.8C
Analysis Area: 1.06899e-01
Detector RF: 5.68108e-08
R.Time Date: 9/23/2013

Start Time: 0.098 min.
Start Signal: 0.000 pA
Sample Amt: 0.2096
R.Factor Date: 9/23/2013

End Time: 28.558 min.
End Signal: 0.000 pA
Solvent Amt: 12.6780

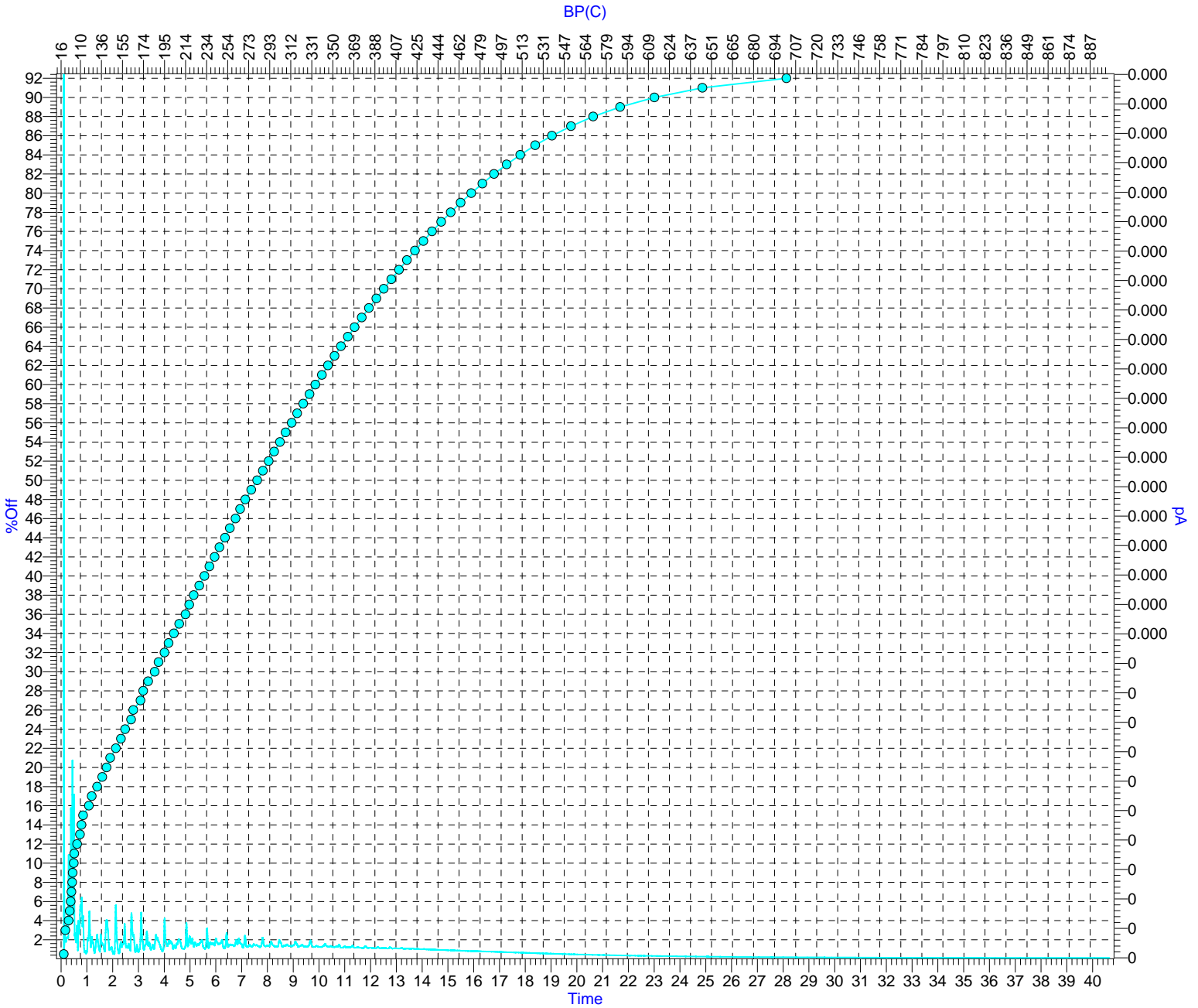
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 Sample: FL13-1205-004
 Parameter: HTSD7169

Distillation Chart

ASTM D7169

Carbon (0) Channel



Recovery: 92.09 @707.8C
Analysis Area: 1.06899e-01
Detector RF: 5.68108e-08
R.Time Date: 9/23/2013

Start Time: 0.098 min.
Start Signal: 0.000 pA
Sample Amt: 0.2096
R.Factor Date: 9/23/2013

End Time: 28.558 min.
End Signal: 0.000 pA
Solvent Amt: 12.6780

Response Factor: 1.40081e-01
R.Time File: O:\SimDData\HPChem\1\data\FL13-1205F 2013-09-20 17-07-04\RT-INITR.D\RT-INITR_FID1_A.CDF
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Attention: SYLVIE DIONNE

TRANSPORTATION SAFETY BOARD OF CANADA
OTTAWA
1901 RESEARCH ROAD
OTTAWA , ON
CANADA K1A 1K8

Report Date: 2013/08/16

Job/Sample	Analysis Type	Well Name/Sample ID	Sample Point
B366426/ HB6491	Certificate of Analysis	TRANSPORTATION SAFETY BOARD OF CANADA R13D0054	NATX 310533-B
B366426/ HB6492	Certificate of Analysis	TRANSPORTATION SAFETY BOARD OF CANADA R13D0054	NATX 310595-B
B366426/ HB6493	Certificate of Analysis	TRANSPORTATION SAFETY BOARD OF CANADA R13D0054	NATX 310406
B366426/ HB6494	Certificate of Analysis	TRANSPORTATION SAFETY BOARD OF CANADA R13D0054	WFIX 130629
B366426/ HB6495	Certificate of Analysis	TRANSPORTATION SAFETY BOARD OF CANADA R13D0054	PROX 44211
B366426/ HB6496	Certificate of Analysis	TRANSPORTATION SAFETY BOARD OF CANADA R13D0054	NATX 310425
B366426/ HB6497	Certificate of Analysis	TRANSPORTATION SAFETY BOARD OF CANADA R13D0054	ACFX 73452
B366426/ HB6498	Certificate of Analysis	TRANSPORTATION SAFETY BOARD OF CANADA R13D0054	NATX 310572
B366426/ HB6499	Certificate of Analysis	TRANSPORTATION SAFETY BOARD OF CANADA R13D0054	NATX 310487
B366426/ HB6500	Certificate of Analysis	TRANSPORTATION SAFETY BOARD OF CANADA FARNHAM R13D0054	NATX 303425
B366426/ HB6501	Certificate of Analysis	TRANSPORTATION SAFETY BOARD OF CANADA FARNHAM R13D0054	PROX 44169

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Victoria Martinek, Project Manager
Email: VMartinek@maxxam.ca
Phone# (780) 378-8554

=====
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports.

Report Distribution

0 Reports(B366426)SYLVIE DIONNE TRANSPORTATION SAFETY BOARD OF CANADA 1901 RESEARCH ROAD OTTAWA , CANADA



CERTIFICATE OF ANALYSIS

B366426:HB6491

MaxxID

Client ID

Meter Number

Laboratory Number

TRANSPORTATION SAFETY BOARD OF CANADA

Operator Name

LSD

Well ID

TRANSPORTATION SAFETY BOARD OF CANADA R13D0054

N/A

TRANSPORTATION SAFETY BOARD OF CANA

Well Name

Initials of Sampler

Sampling Company

NATX 310533-B

GLASS BOTTLE

Field or Area

Pool or Zone

Sample Point

Container Identity

Percent Full

Test Recovery

Interval

Elevations (m)

Sample Gathering Point

Solution Gas

Test Type

No.

Multiple Recovery

From:
To:

KB

GRD

Well Fluid Status

Well Status Mode

Production Rates

Gauge Pressures kPa

Temperature °C

Well Status Type

Well Type

Water m3/d

Oil m3/d

Gas 1000m3/d

Source

As Received

Source

As Received

Gas or Condensate Project

Licence No.

2013/07/17

2013/08/01

2013/08/16

2013/08/16

APC,KMS

Date Sampled Start

Date Sampled End

Date Received

Date Reported

Date Reissued

Analyst

PARAMETER DESCRIPTION

Result

unit

Method

Atmospheric Distillation

Distillation Residue	32.6	vol%	ASTM D86
Distillation Recovery	66.4	vol%	ASTM D86
Distillation Loss	1.0	vol%	ASTM D86
Distillation Naptha	32.4	vol%	ASTM D86
Distillation Kerosene	15.2	vol%	ASTM D86

Distillation Analysis

Initial Boiling Point	46.0	°C	ASTM D86
5 Vol Percent	97.9	°C	ASTM D86
10 Vol Percent	118.4	°C	ASTM D86
15 Vol Percent	135.9	°C	ASTM D86
20 Vol Percent	149.0	°C	ASTM D86
25 Vol Percent	167.2	°C	ASTM D86
30 Vol Percent	193.9	°C	ASTM D86
35 Vol Percent	214.8	°C	ASTM D86
40 Vol Percent	237.9	°C	ASTM D86
45 Vol Percent	261.6	°C	ASTM D86
50 Vol Percent	285.6	°C	ASTM D86
55 Vol Percent	311.4	°C	ASTM D86
60 Vol Percent	336.5	°C	ASTM D86
65 Vol Percent	350.4	°C	ASTM D86
Final Boiling Point	350.4	°C	ASTM D86

Physical Properties

Closed Cup Flash point	<-35	°C	ASTM D93
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** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

Distillation Corrected to 101.3 kPa



CERTIFICATE OF ANALYSIS

B366426:HB6492

<i>MaxxiD</i>	<i>Client ID</i>	<i>Meter Number</i>	<i>Laboratory Number</i>
TRANSPORTATION SAFETY BOARD OF CANADA			
<i>Operator Name</i>		<i>LSD</i>	<i>Well ID</i>
TRANSPORTATION SAFETY BOARD OF CANADA R13D0054		N/A	TRANSPORTATION SAFETY BOARD OF CANA
<i>Well Name</i>		<i>Initials of Sampler</i>	<i>Sampling Company</i>
		NATX 310595-B	GLASS BOTTLE
<i>Field or Area</i>	<i>Pool or Zone</i>	<i>Sample Point</i>	<i>Container Identity</i> <i>Percent Full</i>
<i>Test Recovery</i>		<i>Interval</i>	<i>Elevations (m)</i>
<i>Test Type</i>	<i>No.</i>	<i>Multiple Recovery</i>	<i>Sample Gathering Point</i>
			<i>Well Fluid Status</i>
			<i>Well Status Mode</i>
<i>Production Rates</i>		<i>Gauge Pressures kPa</i>	<i>Temperature °C</i>
<i>Water m3/d</i>	<i>Oil m3/d</i>	<i>Source</i>	<i>Source</i>
		<i>As Received</i>	<i>As Received</i>
			<i>Well Status Type</i>
			<i>Well Type</i>
			<i>Gas or Condensate Project</i>
			<i>Licence No.</i>
2013/07/17	2013/08/01	2013/08/16	2013/08/16
<i>Date Sampled Start</i>	<i>Date Sampled End</i>	<i>Date Received</i>	<i>Date Reported</i>
			<i>Date Reissued</i>
			<i>Analyst</i>
			APC,KMS

PARAMETER DESCRIPTION	Result	unit	Method
Atmospheric Distillation			
Distillation Residue	23.8	vol%	ASTM D86
Distillation Recovery	75.2	vol%	ASTM D86
Distillation Loss	1.0	vol%	ASTM D86
Distillation Naptha	34.7	vol%	ASTM D86
Distillation Kerosene	15.2	vol%	ASTM D86
Distillation Analysis			
Initial Boiling Point	45.5	°C	ASTM D86
5 Vol Percent	92.2	°C	ASTM D86
10 Vol Percent	112.9	°C	ASTM D86
15 Vol Percent	129.2	°C	ASTM D86
20 Vol Percent	144.2	°C	ASTM D86
25 Vol Percent	161.3	°C	ASTM D86
30 Vol Percent	181.4	°C	ASTM D86
35 Vol Percent	205.5	°C	ASTM D86
40 Vol Percent	227.7	°C	ASTM D86
45 Vol Percent	251.9	°C	ASTM D86
50 Vol Percent	274.7	°C	ASTM D86
55 Vol Percent	299.0	°C	ASTM D86
60 Vol Percent	323.8	°C	ASTM D86
65 Vol Percent	347.0	°C	ASTM D86
70 Vol Percent	353.7	°C	ASTM D86
75 Vol Percent	371.4	°C	ASTM D86
Final Boiling Point	373.1	°C	ASTM D86
Physical Properties			
Closed Cup Flash point	<-35	°C	ASTM D93
** Information not supplied by client -- data derived from LSD information			
Results relate only to items tested			

Remarks:

Distillation Corrected to 101.3 kPa



CERTIFICATE OF ANALYSIS

B366426:HB6493

<i>MaxxiD</i>	<i>Client ID</i>	<i>Meter Number</i>	<i>Laboratory Number</i>								
TRANSPORTATION SAFETY BOARD OF CANADA											
<i>Operator Name</i>		<i>LSD</i>	<i>Well ID</i>								
TRANSPORTATION SAFETY BOARD OF CANADA R13D0054		N/A	TRANSPORTATION SAFETY BOARD OF CANA								
<i>Well Name</i>		<i>Initials of Sampler</i>	<i>Sampling Company</i>								
		NATX 310406	GLASS BOTTLE								
<i>Field or Area</i>	<i>Pool or Zone</i>	<i>Sample Point</i>	<i>Container Identity</i> <i>Percent Full</i>								
<i>Test Recovery</i>		<i>Interval</i>	<i>Elevations (m)</i>								
<i>Test Type</i>	<i>No.</i>	<i>Multiple Recovery</i>									
<table border="1" style="width:100%; border-collapse: collapse;"> <tr> <td style="width:33%;"><i>From:</i></td> <td style="width:33%;"><i>To:</i></td> </tr> <tr> <td> </td> <td> </td> </tr> </table>		<i>From:</i>	<i>To:</i>			<table border="1" style="width:100%; border-collapse: collapse;"> <tr> <td style="width:50%;"><i>KB</i></td> <td style="width:50%;"><i>GRD</i></td> </tr> <tr> <td> </td> <td> </td> </tr> </table>	<i>KB</i>	<i>GRD</i>			<i>Sample Gathering Point</i>
<i>From:</i>	<i>To:</i>										
<i>KB</i>	<i>GRD</i>										
			<i>Solution Gas</i>								
<i>Production Rates</i>		<i>Gauge Pressures kPa</i>	<i>Temperature °C</i>								
<i>Water m3/d</i>	<i>Oil m3/d</i>	<i>Gas 1000m3/d</i>									
		<i>Source</i> <i>As Received</i>	<i>Source</i> <i>As Received</i>								
			23.0								
		<i>Well Fluid Status</i>	<i>Well Status Mode</i>								
		<i>Well Status Type</i>	<i>Well Type</i>								
		<i>Gas or Condensate Project</i>	<i>Licence No.</i>								
2013/07/23	2013/08/01	2013/08/16	2013/08/16								
<i>Date Sampled Start</i>	<i>Date Sampled End</i>	<i>Date Received</i>	<i>Date Reported</i>								
			APC,KMS								
			<i>Analyst</i>								

PARAMETER DESCRIPTION	Result	unit	Method
Atmospheric Distillation			
Distillation Residue	26.2	vol%	ASTM D86
Distillation Recovery	72.8	vol%	ASTM D86
Distillation Loss	1.0	vol%	ASTM D86
Distillation Naptha	35.9	vol%	ASTM D86
Distillation Kerosene	15.0	vol%	ASTM D86
Distillation Analysis			
Initial Boiling Point	46.2	°C	ASTM D86
5 Vol Percent	91.5	°C	ASTM D86
10 Vol Percent	111.0	°C	ASTM D86
15 Vol Percent	126.6	°C	ASTM D86
20 Vol Percent	141.7	°C	ASTM D86
25 Vol Percent	157.8	°C	ASTM D86
30 Vol Percent	176.7	°C	ASTM D86
35 Vol Percent	199.5	°C	ASTM D86
40 Vol Percent	223.4	°C	ASTM D86
45 Vol Percent	246.7	°C	ASTM D86
50 Vol Percent	269.7	°C	ASTM D86
55 Vol Percent	293.3	°C	ASTM D86
60 Vol Percent	317.7	°C	ASTM D86
65 Vol Percent	339.9	°C	ASTM D86
70 Vol Percent	350.9	°C	ASTM D86
Final Boiling Point	350.9	°C	ASTM D86
Physical Properties			
Closed Cup Flash point	<-35	°C	ASTM D93
** Information not supplied by client -- data derived from LSD information Results relate only to items tested			

Remarks:
Distillation Corrected to 101.3 kPa



CERTIFICATE OF ANALYSIS

B366426:HB6494

<i>MaxxiD</i>	<i>Client ID</i>	<i>Meter Number</i>	<i>Laboratory Number</i>
TRANSPORTATION SAFETY BOARD OF CANADA			
<i>Operator Name</i>		<i>LSD</i>	<i>Well ID</i>
TRANSPORTATION SAFETY BOARD OF CANADA R13D0054		N/A	TRANSPORTATION SAFETY BOARD OF CANA
<i>Well Name</i>		<i>Initials of Sampler</i>	<i>Sampling Company</i>
		WFIX 130629	GLASS BOTTLE
<i>Field or Area</i>	<i>Pool or Zone</i>	<i>Sample Point</i>	<i>Container Identity</i> <i>Percent Full</i>
<i>Test Recovery</i>		<i>Elevations (m)</i>	<i>Sample Gathering Point</i> <i>Solution Gas</i>
<i>Test Type</i>	<i>No.</i> <i>Multiple Recovery</i>	From: To:	<i>Well Fluid Status</i> <i>Well Status Mode</i>
<i>Production Rates</i>		<i>Gauge Pressures kPa</i>	<i>Well Status Type</i> <i>Well Type</i>
<i>Water m3/d</i>	<i>Oil m3/d</i> <i>Gas 1000m3/d</i>	Source As Received	<i>Gas or Condensate Project</i> <i>Licence No.</i>
2013/07/23		2013/08/01	2013/08/16
<i>Date Sampled Start</i>	<i>Date Sampled End</i>	<i>Date Received</i>	<i>Date Reported</i> <i>Date Reissued</i>
			APC,KMS <i>Analyst</i>

PARAMETER DESCRIPTION	Result	unit	Method
Atmospheric Distillation			
Distillation Residue	32.9	vol%	ASTM D86
Distillation Recovery	66.1	vol%	ASTM D86
Distillation Loss	1.0	vol%	ASTM D86
Distillation Naptha	32.1	vol%	ASTM D86
Distillation Kerosene	15.0	vol%	ASTM D86
Distillation Analysis			
Initial Boiling Point	46.7	°C	ASTM D86
5 Vol Percent	101.2	°C	ASTM D86
10 Vol Percent	121.5	°C	ASTM D86
15 Vol Percent	138.0	°C	ASTM D86
20 Vol Percent	154.0	°C	ASTM D86
25 Vol Percent	171.5	°C	ASTM D86
30 Vol Percent	194.3	°C	ASTM D86
35 Vol Percent	217.3	°C	ASTM D86
40 Vol Percent	240.9	°C	ASTM D86
45 Vol Percent	264.0	°C	ASTM D86
50 Vol Percent	288.0	°C	ASTM D86
55 Vol Percent	314.6	°C	ASTM D86
60 Vol Percent	339.8	°C	ASTM D86
65 Vol Percent	353.8	°C	ASTM D86
Final Boiling Point	353.8	°C	ASTM D86
Physical Properties			
Closed Cup Flash point	<-35	°C	ASTM D93
			Results relate only to items tested

** Information not supplied by client -- data derived from LSD information

Remarks:

Distillation Corrected to 101.3 kPa



CERTIFICATE OF ANALYSIS

B366426:HB6495

<i>MaxxiD</i>	<i>Client ID</i>	<i>Meter Number</i>	<i>Laboratory Number</i>
TRANSPORTATION SAFETY BOARD OF CANADA			
<i>Operator Name</i>		<i>LSD</i>	<i>Well ID</i>
TRANSPORTATION SAFETY BOARD OF CANADA R13D0054		N/A	TRANSPORTATION SAFETY BOARD OF CANA
<i>Well Name</i>		<i>Initials of Sampler</i>	<i>Sampling Company</i>
		PROX 44211	GLASS BOTTLE
<i>Field or Area</i>	<i>Pool or Zone</i>	<i>Sample Point</i>	<i>Container Identity</i> <i>Percent Full</i>
<i>Test Recovery</i>		<i>Elevations (m)</i>	<i>Sample Gathering Point</i> <i>Solution Gas</i>
<i>Test Type</i>	<i>No.</i> <i>Multiple Recovery</i>	From: To:	<i>Well Fluid Status</i> <i>Well Status Mode</i>
<i>Production Rates</i>		<i>Gauge Pressures kPa</i>	<i>Well Status Type</i> <i>Well Type</i>
<i>Water m3/d</i>	<i>Oil m3/d</i> <i>Gas 1000m3/d</i>	Source As Received	<i>Gas or Condensate Project</i> <i>Licence No.</i>
2013/07/23		2013/08/01	2013/08/16
<i>Date Sampled Start</i>	<i>Date Sampled End</i>	<i>Date Received</i>	<i>Date Reported</i> <i>Date Reissued</i>
			APC,KMS
			<i>Analyst</i>

PARAMETER DESCRIPTION	Result	unit	Method
Atmospheric Distillation			
Distillation Residue	23.1	vol%	ASTM D86
Distillation Recovery	75.9	vol%	ASTM D86
Distillation Loss	1.0	vol%	ASTM D86
Distillation Naptha	34.1	vol%	ASTM D86
Distillation Kerosene	15.2	vol%	ASTM D86
Distillation Analysis			
Initial Boiling Point	48.5	°C	ASTM D86
5 Vol Percent	94.0	°C	ASTM D86
10 Vol Percent	115.4	°C	ASTM D86
15 Vol Percent	132.0	°C	ASTM D86
20 Vol Percent	147.9	°C	ASTM D86
25 Vol Percent	164.3	°C	ASTM D86
30 Vol Percent	186.6	°C	ASTM D86
35 Vol Percent	207.6	°C	ASTM D86
40 Vol Percent	232.2	°C	ASTM D86
45 Vol Percent	254.3	°C	ASTM D86
50 Vol Percent	277.0	°C	ASTM D86
55 Vol Percent	300.6	°C	ASTM D86
60 Vol Percent	326.4	°C	ASTM D86
65 Vol Percent	350.4	°C	ASTM D86
70 Vol Percent	356.9	°C	ASTM D86
75 Vol Percent	362.3	°C	ASTM D86
Final Boiling Point	362.4	°C	ASTM D86
Physical Properties			
Closed Cup Flash point	<-35	°C	ASTM D93
** Information not supplied by client -- data derived from LSD information Results relate only to items tested			

Remarks:
Distillation Corrected to 101.3 kPa



CERTIFICATE OF ANALYSIS

B366426:HB6496

MaxxID _____ Client ID _____ Meter Number _____ Laboratory Number _____

TRANSPORTATION SAFETY BOARD OF CANADA

Operator Name _____ LSD _____ Well ID _____

TRANSPORTATION SAFETY BOARD OF CANADA R13D0054 N/A TRANSPORTATION SAFETY BOARD OF CANA

Well Name _____ Initials of Sampler _____ Sampling Company _____

Field or Area _____ Pool or Zone _____ Sample Point _____ Container Identity _____ Percent Full _____

NATX 310425 GLASS BOTTLE

Test Recovery _____ Interval _____ Elevations (m) _____ Sample Gathering Point _____ Solution Gas _____

Test Type _____ No. _____ Multiple Recovery _____ From: _____ To: _____ KB _____ GRD _____ Well Fluid Status _____ Well Status Mode _____

Production Rates _____ Gauge Pressures kPa _____ Temperature °C _____ Well Status Type _____ Well Type _____

Water m3/d _____ Oil m3/d _____ Gas 1000m3/d _____ Source _____ As Received _____ Source _____ As Received _____ 23.0 _____ Gas or Condensate Project _____ Licence No. _____

2013/07/23 _____ 2013/08/01 _____ 2013/08/16 _____ 2013/08/16 _____ APC,KMS

Date Sampled Start _____ Date Sampled End _____ Date Received _____ Date Reported _____ Date Reissued _____ Analyst _____

PARAMETER DESCRIPTION	Result	unit	Method
Atmospheric Distillation			
Distillation Residue	34.3	vol%	ASTM D86
Distillation Recovery	64.7	vol%	ASTM D86
Distillation Loss	1.0	vol%	ASTM D86
Distillation Naptha	31.2	vol%	ASTM D86
Distillation Kerosene	14.8	vol%	ASTM D86
Distillation Analysis			
Initial Boiling Point	44.7	°C	ASTM D86
5 Vol Percent	99.5	°C	ASTM D86
10 Vol Percent	120.1	°C	ASTM D86
15 Vol Percent	137.7	°C	ASTM D86
20 Vol Percent	155.3	°C	ASTM D86
25 Vol Percent	174.8	°C	ASTM D86
30 Vol Percent	198.6	°C	ASTM D86
35 Vol Percent	220.7	°C	ASTM D86
40 Vol Percent	244.4	°C	ASTM D86
45 Vol Percent	268.8	°C	ASTM D86
50 Vol Percent	293.3	°C	ASTM D86
55 Vol Percent	318.7	°C	ASTM D86
60 Vol Percent	342.0	°C	ASTM D86
Final Boiling Point	349.2	°C	ASTM D86
Physical Properties			
Closed Cup Flash point	<-35	°C	ASTM D93

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

Distillation Corrected to 101.3 kPa



CERTIFICATE OF ANALYSIS

B366426:HB6497

MaxxiD		Client ID		Meter Number	Laboratory Number
TRANSPORTATION SAFETY BOARD OF CANADA				LSD	Well ID
Operator Name TRANSPORTATION SAFETY BOARD OF CANADA R13D0054				N/A	TRANSPORTATION SAFETY BOARD OF CANA
Well Name				Initials of Sampler	Sampling Company
Field or Area				ACFX 73452	GLASS BOTTLE
Pool or Zone		Sample Point		Container Identity	Percent Full
Test Recovery		Interval		Elevations (m)	
Test Type	No.	From: To:		KB	GRD
Multiple Recovery		Gauge Pressures kPa		Sample Gathering Point	
Production Rates		Source		Solution Gas	
Water m3/d	Oil m3/d	As Received		Well Fluid Status	
Gas 1000m3/d		Source		Well Status Mode	
Temperature °C		As Received		Well Status Type	
23.0		Source		Well Type	
Gas or Condensate Project		Licence No.		Date Sampled Start	
2013/07/23		2013/08/01		2013/08/16	
Date Sampled End		Date Received		Date Reported	
2013/08/16		2013/08/16		2013/08/16	
Date Reissued		Analyst		APC,KMS	

PARAMETER DESCRIPTION	Result	unit	Method
Atmospheric Distillation			
Distillation Residue	19.7	vol%	ASTM D86
Distillation Recovery	79.3	vol%	ASTM D86
Distillation Loss	1.0	vol%	ASTM D86
Distillation Naptha	32.4	vol%	ASTM D86
Distillation Kerosene	15.2	vol%	ASTM D86
Distillation Analysis			
Initial Boiling Point	48.5	°C	ASTM D86
5 Vol Percent	97.6	°C	ASTM D86
10 Vol Percent	119.2	°C	ASTM D86
15 Vol Percent	136.8	°C	ASTM D86
20 Vol Percent	151.8	°C	ASTM D86
25 Vol Percent	172.3	°C	ASTM D86
30 Vol Percent	194.4	°C	ASTM D86
35 Vol Percent	214.8	°C	ASTM D86
40 Vol Percent	239.1	°C	ASTM D86
45 Vol Percent	262.9	°C	ASTM D86
50 Vol Percent	284.7	°C	ASTM D86
55 Vol Percent	309.4	°C	ASTM D86
60 Vol Percent	334.4	°C	ASTM D86
65 Vol Percent	354.4	°C	ASTM D86
70 Vol Percent	358.9	°C	ASTM D86
75 Vol Percent	362.9	°C	ASTM D86
Final Boiling Point	362.9	°C	ASTM D86
Physical Properties			
Closed Cup Flash point	<-35	°C	ASTM D93

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:
Distillation Corrected to 101.3 kPa



CERTIFICATE OF ANALYSIS

B366426:HB6498

MaxxiD Client ID Meter Number Laboratory Number

TRANSPORTATION SAFETY BOARD OF CANADA

Operator Name LSD Well ID

TRANSPORTATION SAFETY BOARD OF CANADA R13D0054 N/A TRANSPORTATION SAFETY BOARD OF CANA

Well Name Initials of Sampler Sampling Company

NATX 310572 GLASS BOTTLE

Field or Area Pool or Zone Sample Point Container Identity Percent Full

Test Recovery Interval Elevations (m) Sample Gathering Point Solution Gas

Test Type No. Multiple Recovery From: To: KB GRD Well Fluid Status Well Status Mode

Production Rates Gauge Pressures kPa Temperature °C Well Status Type Well Type

Water m3/d Oil m3/d Gas 1000m3/d Source As Received Source As Received Gas or Condensate Project Licence No.

2013/07/23 2013/08/01 2013/08/16 2013/08/16 APC,KMS
 Date Sampled Start Date Sampled End Date Received Date Reported Date Reissued Analyst

PARAMETER DESCRIPTION	Result	unit	Method
Atmospheric Distillation			
Distillation Residue	30.3	vol%	ASTM D86
Distillation Recovery	68.7	vol%	ASTM D86
Distillation Loss	1.0	vol%	ASTM D86
Distillation Naptha	33.3	vol%	ASTM D86
Distillation Kerosene	15.2	vol%	ASTM D86
Distillation Analysis			
Initial Boiling Point	43.9	°C	ASTM D86
5 Vol Percent	95.7	°C	ASTM D86
10 Vol Percent	117.2	°C	ASTM D86
15 Vol Percent	134.7	°C	ASTM D86
20 Vol Percent	149.9	°C	ASTM D86
25 Vol Percent	168.1	°C	ASTM D86
30 Vol Percent	189.7	°C	ASTM D86
35 Vol Percent	211.6	°C	ASTM D86
40 Vol Percent	233.6	°C	ASTM D86
45 Vol Percent	258.5	°C	ASTM D86
50 Vol Percent	281.0	°C	ASTM D86
55 Vol Percent	306.3	°C	ASTM D86
60 Vol Percent	332.1	°C	ASTM D86
65 Vol Percent	355.7	°C	ASTM D86
Final Boiling Point	363.5	°C	ASTM D86
Physical Properties			
Closed Cup Flash point	<-35	°C	ASTM D93

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

Distillation Corrected to 101.3 kPa



CERTIFICATE OF ANALYSIS

B366426:HB6499

<i>MaxxiD</i>	<i>Client ID</i>	<i>Meter Number</i>	<i>Laboratory Number</i>
TRANSPORTATION SAFETY BOARD OF CANADA			
<i>Operator Name</i>		<i>LSD</i>	<i>Well ID</i>
TRANSPORTATION SAFETY BOARD OF CANADA R13D0054		N/A	TRANSPORTATION SAFETY BOARD OF CANA
<i>Well Name</i>		<i>Initials of Sampler</i>	<i>Sampling Company</i>
		NATX 310487	GLASS BOTTLE
<i>Field or Area</i>	<i>Pool or Zone</i>	<i>Sample Point</i>	<i>Container Identity</i> <i>Percent Full</i>
<i>Test Recovery</i>		<i>Interval</i>	<i>Elevations (m)</i>
<i>Test Type</i>	<i>No.</i>	<i>Multiple Recovery</i>	<i>Sample Gathering Point</i>
			<i>Well Fluid Status</i>
			<i>Well Status Mode</i>
<i>Production Rates</i>		<i>Gauge Pressures kPa</i>	<i>Temperature °C</i>
<i>Water m3/d</i>	<i>Oil m3/d</i>	<i>Source</i>	<i>Source</i>
		<i>As Received</i>	<i>As Received</i>
			<i>Well Status Type</i>
			<i>Well Type</i>
			<i>Gas or Condensate Project</i>
			<i>Licence No.</i>
2013/07/23	2013/08/01	2013/08/16	2013/08/16
<i>Date Sampled Start</i>	<i>Date Sampled End</i>	<i>Date Received</i>	<i>Date Reissued</i>
			APC,KMS
			<i>Analyst</i>

PARAMETER DESCRIPTION	Result	unit	Method
Atmospheric Distillation			
Distillation Residue	31.7	vol%	ASTM D86
Distillation Recovery	67.3	vol%	ASTM D86
Distillation Loss	1.0	vol%	ASTM D86
Distillation Naptha	33.7	vol%	ASTM D86
Distillation Kerosene	14.5	vol%	ASTM D86
Distillation Analysis			
Initial Boiling Point	46.3	°C	ASTM D86
5 Vol Percent	95.7	°C	ASTM D86
10 Vol Percent	117.5	°C	ASTM D86
15 Vol Percent	134.4	°C	ASTM D86
20 Vol Percent	150.7	°C	ASTM D86
25 Vol Percent	167.7	°C	ASTM D86
30 Vol Percent	187.4	°C	ASTM D86
35 Vol Percent	209.8	°C	ASTM D86
40 Vol Percent	235.1	°C	ASTM D86
45 Vol Percent	259.6	°C	ASTM D86
50 Vol Percent	281.8	°C	ASTM D86
55 Vol Percent	307.1	°C	ASTM D86
60 Vol Percent	333.1	°C	ASTM D86
65 Vol Percent	349.5	°C	ASTM D86
Final Boiling Point	350.3	°C	ASTM D86
Physical Properties			
Closed Cup Flash point	<-35	°C	ASTM D93
** Information not supplied by client -- data derived from LSD information Results relate only to items tested			

Remarks:
Distillation Corrected to 101.3 kPa



CERTIFICATE OF ANALYSIS

B366426:HB6500

<i>MaxxiD</i>	<i>Client ID</i>	<i>Meter Number</i>	<i>Laboratory Number</i>
TRANSPORTATION SAFETY BOARD OF CANADA			
<i>Operator Name</i>		<i>LSD</i>	<i>Well ID</i>
TRANSPORTATION SAFETY BOARD OF CANADA FARNHAM R13D0054		N/A	TRANSPORTATION SAFETY BOARD OF CANA
<i>Well Name</i>		<i>Initials of Sampler</i>	<i>Sampling Company</i>
		NATX 303425	GLASS BOTTLE
<i>Field or Area</i>	<i>Pool or Zone</i>	<i>Sample Point</i>	<i>Container Identity</i> <i>Percent Full</i>
<i>Test Recovery</i>		<i>Elevations (m)</i>	<i>Sample Gathering Point</i> <i>Solution Gas</i>
<i>Test Type</i>	<i>No.</i> <i>Multiple Recovery</i>	From: _____ To: _____	<i>Well Fluid Status</i> <i>Well Status Mode</i>
<i>Production Rates</i>		KB _____ GRD _____	<i>Well Status Type</i> <i>Well Type</i>
Water m3/d	Oil m3/d	Gas 1000m3/d	<i>Gas or Condensate Project</i> <i>Licence No.</i>
<i>Gauge Pressures kPa</i>		Temperature °C	
Source _____	As Received _____	23.0	
		Source _____	As Received _____
2013/07/25	2013/08/01	2013/08/16	2013/08/16
<i>Date Sampled Start</i>	<i>Date Sampled End</i>	<i>Date Received</i>	<i>Date Reissued</i>
			APC,KMS
			<i>Analyst</i>

PARAMETER DESCRIPTION	Result	unit	Method
Atmospheric Distillation			
Distillation Residue	33.8	vol%	ASTM D86
Distillation Recovery	65.2	vol%	ASTM D86
Distillation Loss	1.0	vol%	ASTM D86
Distillation Naptha	31.3	vol%	ASTM D86
Distillation Kerosene	14.9	vol%	ASTM D86
Distillation Analysis			
Initial Boiling Point	46.2	°C	ASTM D86
5 Vol Percent	101.1	°C	ASTM D86
10 Vol Percent	121.8	°C	ASTM D86
15 Vol Percent	139.9	°C	ASTM D86
20 Vol Percent	157.9	°C	ASTM D86
25 Vol Percent	176.5	°C	ASTM D86
30 Vol Percent	198.5	°C	ASTM D86
35 Vol Percent	220.5	°C	ASTM D86
40 Vol Percent	244.7	°C	ASTM D86
45 Vol Percent	268.2	°C	ASTM D86
50 Vol Percent	293.2	°C	ASTM D86
55 Vol Percent	318.5	°C	ASTM D86
60 Vol Percent	344.4	°C	ASTM D86
65 Vol Percent	361.1	°C	ASTM D86
Final Boiling Point	361.1	°C	ASTM D86
Physical Properties			
Closed Cup Flash point	<-35	°C	ASTM D93
** Information not supplied by client -- data derived from LSD information			
Results relate only to items tested			

Remarks:

Distillation Corrected to 101.3 kPa



CERTIFICATE OF ANALYSIS

B366426:HB6501

MaxxiD Client ID Meter Number Laboratory Number

TRANSPORTATION SAFETY BOARD OF CANADA

Operator Name LSD Well ID

TRANSPORTATION SAFETY BOARD OF CANADA FARNHAM R13D0054 N/A TRANSPORTATION SAFETY BOARD OF CANA

Well Name Initials of Sampler Sampling Company

Field or Area Pool or Zone Sample Point Container Identity Percent Full

PROX 44169 GLASS BOTTLE

Test Recovery Interval Elevations (m) Sample Gathering Point Solution Gas

Test Type No. Multiple Recovery From: To: KB GRD Well Fluid Status Well Status Mode

Production Rates Gauge Pressures kPa Temperature °C Well Status Type Well Type

Water m3/d Oil m3/d Gas 1000m3/d Source As Received Source As Received Gas or Condensate Project Licence No.

2013/07/25 2013/08/01 2013/08/16 2013/08/16 APC,KMS

Date Sampled Start Date Sampled End Date Received Date Reported Date Reissued Analyst

PARAMETER DESCRIPTION	Result	unit	Method
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Atmospheric Distillation

Distillation Residue	32.8	vol%	ASTM D86
Distillation Recovery	66.2	vol%	ASTM D86
Distillation Loss	1.0	vol%	ASTM D86
Distillation Naptha	32.2	vol%	ASTM D86
Distillation Kerosene	15.1	vol%	ASTM D86

Distillation Analysis

Initial Boiling Point	46.3	°C	ASTM D86
5 Vol Percent	97.0	°C	ASTM D86
10 Vol Percent	118.9	°C	ASTM D86
15 Vol Percent	136.3	°C	ASTM D86
20 Vol Percent	151.9	°C	ASTM D86
25 Vol Percent	172.0	°C	ASTM D86
30 Vol Percent	194.7	°C	ASTM D86
35 Vol Percent	216.1	°C	ASTM D86
40 Vol Percent	239.0	°C	ASTM D86
45 Vol Percent	263.0	°C	ASTM D86
50 Vol Percent	287.5	°C	ASTM D86
55 Vol Percent	312.2	°C	ASTM D86
60 Vol Percent	337.6	°C	ASTM D86
65 Vol Percent	350.6	°C	ASTM D86
Final Boiling Point	351.0	°C	ASTM D86

Physical Properties

Closed Cup Flash point	<-35	°C	ASTM D93
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** Information not supplied by client -- data derived from LSD information Results relate only to items tested

Remarks:
Distillation Corrected to 101.3 kPa



Attention: WENDY BRYSON

TRANSPORTATION SAFETY BOARD OF CANADA
OTTAWA
1901 RESEARCH ROAD
OTTAWA , ON
CANADA K1A 1K8

Report Date: 2013/10/17

Job/Sample	Analysis Type	Well Name/Sample ID	Sample Point
B391775/ HS9845	Certificate of Analysis	TRANSPORTATION SAFETY BOARD	NATX 310572-C-TOP
B391775/ HS9846	Certificate of Analysis	TRANSPORTATION SAFETY BOARD	NATX 310572-C-BOT
B391775/ HS9847	Certificate of Analysis	TRANSPORTATION SAFETY BOARD	PROX 44211-C-TOP
B391775/ HS9848	Certificate of Analysis	TRANSPORTATION SAFETY BOARD	PROX 44211-C-BOT

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Victoria Martinek, Project Manager
Email: VMartinek@maxxam.ca
Phone# (780) 378-8554

=====

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports.

Report Distribution

0	Reports(B391775)WENDY BRYSON	TRANSPORTATION SAFETY BOARD OF CANADA	1901 RESEARCH ROAD	OTTAWA , CANADA
0	Reports(B391775)SYLVIE DIONNE	TRANSPORTATION SAFETY BOARD OF CANADA	1901 RESEARCH ROAD	OTTAWA , CANADA



CERTIFICATE OF ANALYSIS

B391775:HS9845

MaxxID Client ID Meter Number Laboratory Number

TRANSPORTATION SAFETY BOARD OF CANADA

Operator Name LSD Well ID

TRANSPORTATION SAFETY BOARD N/A TRANSPORTATION SAFETY BOARD

Well Name Initials of Sampler Sampling Company

Field or Area Pool or Zone Sample Point Container Identity Percent Full

NATX 310572-C-TOP GLASS BOTTLE

Test Recovery Interval Elevations (m) Sample Gathering Point Solution Gas

Test Type No. Multiple Recovery From: To: KB GRD Well Fluid Status Well Status Mode

Production Rates Gauge Pressures kPa Temperature °C Well Status Type Well Type

Water m3/d Oil m3/d Gas 1000m3/d Source As Received Source As Received Gas or Condensate Project Licence No.

2013/10/07 2013/10/17 2013/10/17 SK1,NH4,KL9,MPW,BS7

Date Sampled Start Date Sampled End Date Received Date Reported Date Reissued Analyst

PARAMETER DESCRIPTION	Result	unit	Method
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Density Analysis

Absolute Density @ 15 °C	815.9	kg/m3	ASTM D5002
Measured Relative Density @ 15 °C	0.8166	N/A	ASTM D5002
API Gravity @ 15 °C	41.8	N/A	

Heat of Combustion

Measured Gross Heat of Combustion	19247	BTU/lb	ASTM D240
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Physical Properties

Pour Point	<-65	°C	ASTM D5853
Reid Vapour Pressure	66.1	kPa	ASTM D323A
Total Sulphur (S)	0.096	mass%	ASTM D4294

Viscosity Analysis

Viscosity @ 20°C	2.882	cSt	ASTM D7042
Viscosity @ 30°C	2.295	cSt	ASTM D7042
Viscosity @ 10°C	3.639	cSt	ASTM D7042
Viscosity @ 40°C	1.910	cSt	ASTM D7042

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

SAMPLE DATE NOT RECORDED
Viscosity at 10C was extrapolated from 20, 30, 40C.



CERTIFICATE OF ANALYSIS

B391775:HS9846

MaxxID _____ Client ID _____ Meter Number _____ Laboratory Number _____

TRANSPORTATION SAFETY BOARD OF CANADA

Operator Name _____ LSD _____ Well ID _____

TRANSPORTATION SAFETY BOARD _____ N/A _____ TRANSPORTATION SAFETY BOARD _____

Well Name _____ Initials of Sampler _____ Sampling Company _____

Field or Area _____ Pool or Zone _____ Sample Point _____ Container Identity _____ Percent Full _____

NATX 310572-C-BOT _____ GLASS BOTTLE _____

Test Recovery _____ Interval _____ Elevations (m) _____ Sample Gathering Point _____ Solution Gas _____

Test Type _____ No. _____ Multiple Recovery _____ From: _____ To: _____ KB _____ GRD _____ Well Fluid Status _____ Well Status Mode _____

Production Rates _____ Gauge Pressures kPa _____ Temperature °C _____ Well Status Type _____ Well Type _____

Water m3/d _____ Oil m3/d _____ Gas 1000m3/d _____ Source _____ As Received _____ Source _____ As Received _____ 23.0 _____ Gas or Condensate Project _____ Licence No. _____

2013/10/07 _____ 2013/10/17 _____ 2013/10/17 _____ SK1,NH4,KL9,MPW,BS7

Date Sampled Start _____ Date Sampled End _____ Date Received _____ Date Reported _____ Date Reissued _____ Analyst _____

PARAMETER DESCRIPTION	Result	unit	Method
Density Analysis			
Absolute Density @ 15 °C	816.5	kg/m3	ASTM D5002
Measured Relative Density @ 15 °C	0.8172	N/A	ASTM D5002
API Gravity @ 15 °C	41.7	N/A	
Heat of Combustion			
Measured Gross Heat of Combustion	18445	BTU/lb	ASTM D240
Physical Properties			
Pour Point	<-65	°C	ASTM D5853
Reid Vapour Pressure	64.3	kPa	ASTM D323A
Total Sulphur (S)	0.096	mass%	ASTM D4294
Viscosity Analysis			
Viscosity @ 20°C	2.982	cSt	ASTM D7042
Viscosity @ 30°C	2.467	cSt	ASTM D7042
Viscosity @ 10°C	3.720	cSt	ASTM D7042
Viscosity @ 40°C	2.080	cSt	ASTM D7042

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

SAMPLE DATE NOT RECORDED
Viscosity at 10C was extrapolated from 20, 30, 40C.



CERTIFICATE OF ANALYSIS

B391775:HS9847

MaxxID Client ID Meter Number Laboratory Number

TRANSPORTATION SAFETY BOARD OF CANADA

Operator Name LSD Well ID

TRANSPORTATION SAFETY BOARD N/A TRANSPORTATION SAFETY BOARD

Well Name Initials of Sampler Sampling Company

Field or Area Pool or Zone Sample Point Container Identity Percent Full

PROX 44211-C-TOP GLASS BOTTLE

Test Recovery Interval Elevations (m) Sample Gathering Point Solution Gas

Test Type No. Multiple Recovery From: To: KB GRD Well Fluid Status Well Status Mode

Production Rates Gauge Pressures kPa Temperature °C Well Status Type Well Type

Water m3/d Oil m3/d Gas 1000m3/d Source As Received Source As Received Gas or Condensate Project Licence No.

2013/10/07 2013/10/17 2013/10/17 SK1,NH4,KL9,MPW,BS7

Date Sampled Start Date Sampled End Date Received Date Reported Date Reissued Analyst

PARAMETER DESCRIPTION	Result	unit	Method
Density Analysis			
Absolute Density @ 15 °C	821.9	kg/m3	ASTM D5002
Measured Relative Density @ 15 °C	0.8226	N/A	ASTM D5002
API Gravity @ 15 °C	40.5	N/A	
Heat of Combustion			
Measured Gross Heat of Combustion	19416	BTU/lb	ASTM D240
Physical Properties			
Pour Point	<-65	°C	ASTM D5853
Reid Vapour Pressure	62.3	kPa	ASTM D323A
Total Sulphur (S)	0.117	mass%	ASTM D4294
Viscosity Analysis			
Viscosity @ 20°C	3.259	cSt	ASTM D7042
Viscosity @ 30°C	2.665	cSt	ASTM D7042
Viscosity @ 10°C	4.100	cSt	ASTM D7042
Viscosity @ 40°C	2.230	cSt	ASTM D7042

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

SAMPLE DATE NOT RECORDED
Viscosity at 10C was extrapolated from 20, 30, 40C.



CERTIFICATE OF ANALYSIS

B391775:HS9848

MaxxID Client ID Meter Number Laboratory Number

TRANSPORTATION SAFETY BOARD OF CANADA

Operator Name LSD Well ID

TRANSPORTATION SAFETY BOARD N/A TRANSPORTATION SAFETY BOARD

Well Name Initials of Sampler Sampling Company

Field or Area Pool or Zone Sample Point Container Identity Percent Full

PROX 44211-C-BOT GLASS BOTTLE

Test Recovery Interval Elevations (m) Sample Gathering Point Solution Gas

Test Type No. Multiple Recovery From: To: KB GRD Well Fluid Status Well Status Mode

Production Rates Gauge Pressures kPa Temperature °C Well Status Type Well Type

Water m3/d Oil m3/d Gas 1000m3/d Source As Received Source As Received Gas or Condensate Project Licence No.

2013/10/07 2013/10/17 2013/10/17 MS7,SK1,KL9,MPW,BS7

Date Sampled Start Date Sampled End Date Received Date Reported Date Reissued Analyst

PARAMETER DESCRIPTION	Result	unit	Method
Density Analysis			
Absolute Density @ 15 °C	821.8	kg/m3	ASTM D5002
Measured Relative Density @ 15 °C	0.8225	N/A	ASTM D5002
API Gravity @ 15 °C	40.5	N/A	
Heat of Combustion			
Measured Gross Heat of Combustion	19164	BTU/lb	ASTM D240
Physical Properties			
Pour Point	<-65	°C	ASTM D5853
Reid Vapour Pressure	62.4	kPa	ASTM D323A
Total Sulphur (S)	0.117	mass%	ASTM D4294
Viscosity Analysis			
Viscosity @ 20°C	3.220	cSt	ASTM D7042
Viscosity @ 30°C	2.548	cSt	ASTM D7042
Viscosity @ 10°C	4.078	cSt	ASTM D7042
Viscosity @ 40°C	2.205	cSt	ASTM D7042

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

SAMPLE DATE NOT RECORDED
Viscosity at 10C was extrapolated from 20, 30, 40C.



October 11, 2013

Sylvie Dionne
Transportation Safety Board of Canada
1901 Research Road
Ottawa, Ontario
K1A 1K8

**RE: Analytical Report for Transportation Safety Board of Canada Project: N/A
CASSEN Work Order No. 2505040**

Dear Sylvie,

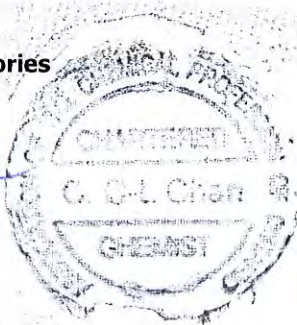
We have completed the analysis of the 4 Bulk Liquid samples that you submitted on October 04, 2013 for the determination of BTEX using gas chromatography mass spectrometry. Results of the analysis are summarized in the attached report, which includes the method description and quality control data.

Sylvie, please feel free to give me a call at (416) 679-9663 should you need any clarification. Thank you for using our services.

Sincerely,

CASSEN Testing Laboratories

Cecilia Chan, M.Sc., C.Chem
Laboratory Director



Determination of Target Analytes in Bulk Liquids, Using Gas Chromatography/Mass Spectrometry

Brief Description of the Method:

The sample was diluted with appropriate solvent then injected directly into a capillary column of GC/MS system for quantification of the target analytes.

CASSEN method #: M.3005.R0

Method Reference:

"Characteristics of Spilled Oils, Fuels, and Petroleum Products: 1. Composition and Properties of Selected Oils",
EPA 600/R-03/072, July 2003

Analytical System:

Instrument:

GC/MS System:	Varian Model CP-3800 Gas Chromatograph coupled with Varian Saturn 2200 MS/MS system
Autosampler:	Varian CP 8400 Autosampler
Data System:	Varian MS-Workstation Data Review system
LIM System:	CAS-LIMS Laboratory Information System

Sampling Media: Bulk Liquid



CASSEN Testing Laboratories

51 International Blvd., Toronto, Ontario, M9W 6H3
Tel: (416) 679-9663 Fax: (416) 679-9668 Web: www.cassen.ca

Analytical Results

Date: October 10, 2013

Organization: Transportation Safety Board of Canada
Address: 1901 Research Road, Ottawa, Ontario, K1A 1K8
Contact: Sylvie Dionne
Project: N/A

Work Order No.: 2505040
Date Received: October 04, 2013

Analysis Requested: BTEX
CASSEN Method: M.3005.R0 No. of Samples: 4
Reference Method: EPA 600/R-03/072 No. of Blanks: 0
Sampling Media: Bulk Sample

Sample Identification: R13D0054-BTEX-1
Mass (g): 0.8152
Date Sampled: August 07, 2013
Date Analyzed: October 08, 2013

#	Analyte	CAS	Analytical Results		
			Total (ug)	(ug/g)	(ppm)
1	Benzene	000071-43-2	1510	1850	1850
2	Toluene	000108-88-3	2580	3170	3170
3	Ethylbenzene	000100-41-4	693	850	850
4	m/p-Xylene	000106-42-3	2850	3500	3500
5	o-Xylene	000095-47-6	1350	1660	1660

Sample Identification: R13D0054-BTEX-2
Mass (g): 0.8167
Date Sampled: August 07, 2013
Date Analyzed: October 08, 2013

#	Analyte	CAS	Analytical Results		
			Total (ug)	(ug/g)	(ppm)
1	Benzene	000071-43-2	1410	1720	1720
2	Toluene	000108-88-3	2340	2870	2870
3	Ethylbenzene	000100-41-4	627	768	768
4	m/p-Xylene	000106-42-3	2690	3300	3300
5	o-Xylene	000095-47-6	1270	1560	1560

Sample Identification: R13D0054-BTEX-3
Mass (g): 0.8161
Date Sampled: August 07, 2013
Date Analyzed: October 08, 2013

#	Analyte	CAS	Analytical Results		
			Total (ug)	(ug/g)	(ppm)
1	Benzene	000071-43-2	1470	1800	1800
2	Toluene	000108-88-3	2380	2920	2920
3	Ethylbenzene	000100-41-4	644	789	789
4	m/p-Xylene	000106-42-3	2700	3310	3310
5	o-Xylene	000095-47-6	1320	1620	1620

Notes:

- 1) <: Less than the indicated instrument detection limit (IDL).
- 2) N.A.: Information not available or not applicable.
- 3) The results have been lab blank subtracted.
- 4) This **Certificate of Analysis** shall not be reproduced except in full, without written approval of the laboratory. These analytical results pertain only to the samples as received in the laboratory. No responsibility or liability is assumed for the manner in which the results are used.



CASSEN Testing Laboratories

51 International Blvd., Toronto, Ontario, M9W 6H3
Tel: (416) 679-9663 Fax: (416) 679-9668 Web: www.cassen.ca

Analytical Results

Date: October 10, 2013

Organization: Transportation Safety Board of Canada
Address: 1901 Research Road, Ottawa, Ontario, K1A 1K8
Contact: Sylvie Dionne
Project: N/A

Work Order No.: 2505040
Date Received: October 04, 2013

Sample Identification: R13D0054-BTEX-4
Mass (g): 0.8201

Date Sampled: August 07, 2013
Date Analyzed: October 08, 2013

#	Analyte	CAS	Analytical Results		
			Total (ug)	(ug/g)	(ppm)
1	Benzene	000071-43-2	1200	1470	1470
2	Toluene	000108-88-3	2270	2770	2770
3	Ethylbenzene	000100-41-4	699	852	852
4	m/p-Xylene	000106-42-3	2370	2890	2890
5	o-Xylene	000095-47-6	1230	1500	1500

Notes:

- 1) <: Less than the indicated instrument detection limit (IDL).
- 2) N.A.: Information not available or not applicable.
- 3) The results have been lab blank subtracted.
- 4) This *Certificate of Analysis* shall not be reproduced except in full, without written approval of the laboratory. These analytical results pertain only to the samples as received in the laboratory. No responsibility or liability is assumed for the manner in which the results are used.



CASSEN Testing Laboratories

51 International Blvd., Toronto, Ontario, M9W 6H3
Tel: (416) 679-9663 Fax: (416) 679-9668 Web: www.cassen.ca

Analytical Results

Date: October 10, 2013

Organization: Transportation Safety Board of Canada
Address: 1901 Research Road, Ottawa, Ontario, K1A 1K8
Contact: Sylvie Dionne
Project: N/A

Work Order No.: 2505040
Date Received: October 04, 2013

Quality Control Batch #: 12285-153

#	Analyte	CAS	Uncertainty %	IDL (ug)
1	Benzene	000071-43-2	8.91	0.00005
2	Toluene	000108-88-3	7.80	0.00005
3	Ethylbenzene	000100-41-4	12.05	0.00005
4	m/p-Xylene	000106-42-3	11.52	0.00005
5	o-Xylene	000095-47-6	10.87	0.00005

Notes:

Analyst:

Matthew Yao, M.Sc., Chemist

Reviewer:

Queenie Yip, B.Sc., C/Chem., Senior Chemist



Notes:

- 1) <: Less than the indicated instrument detection limit (IDL).
- 2) N.A.: Information not available or not applicable.
- 3) The results have been lab blank subtracted.
- 4) This **Certificate of Analysis** shall not be reproduced except in full, without written approval of the laboratory. These analytical results pertain only to the samples as received in the laboratory. No responsibility or liability is assumed for the manner in which the results are used.



CASSEN Testing Laboratories

Division of CASSEN Group Inc.

ANALYTICAL SERVICES REQUEST FORM

51 International Blvd.
Toronto, ON M9W 6H3
Tel: (416) 679-9663
Fax: (416) 679-9668
Toll Free: 1-866-423-3001
Web: www.cassen.ca

FOR CASSEN USE ONLY
CASSEN Work Order No:

2505040

Send Report To:

Check if this is a new address

Company: Transportation Safety Board of Canada
Address: 1901 Research Road
City: Ottawa Province: Ontario
Attention: Sylvie Dionne Postal Code: K1A1K8
Phone: 613-949-3949 Fax: 613-998-5572
Email: Sylvie.Dionne@tsb-bst.gc.ca

Invoice To (if different):

Check if this is a new address

Company: Transportation Safety Board of Canada
Address: 1901 Research Road
City: Ottawa Province: Ontario
Attention: Wendy Bryson Postal Code: K1A1K8
Phone: 613-990-0776 Fax: 613-998-5572
Email: Wendy.Bryson@tsb-bst.gc.ca

Required Turnaround Time

Regular Routine Analysis Turnaround Time (5 Days)*
 Open Characterization with Interpretation Requires 8 Days* TAT
 Rush Analysis Options (Please Call Ahead)
 8 Hours 24 Hours 48 Hours 72 Hours

Project Name / Number: _____ Sampled By: _____ P.O. Number: _____ Sampling Data Sheet Attached

Client Sample Number Description/Identification	Date Sampled (DD/MM/YYYY)	Sample Type	Active Sample Volume (L)	Passive Sample Time (mins)	Analysis Requested	Comment
R13D0054-BTEX-1	07/08/2013	crude oil			BTEX using GC/MS	
R13D0054-BTEX-2	07/08/2013	crude oil			BTEX using GC/MS	
R13D0054-BTEX-3	07/08/2013	crude oil			BTEX using GC/MS	
R13D0054-BTEX-4	07/08/2013	crude oil			BTEX using GC/MS	

Special Instructions
As discussed with Cecilia Chan, we require a detection limit of 0.1 ppm (benzene) and 1 ppm (toluene, ethyl benzene, m,p,o-xylene).

CHAIN OF CUSTODY	Print Name	Signature	Date (DD/MM/YYYY)	Time	Sample Condition Upon Receipt
Relinquished by:	John Ferguson	<i>[Signature]</i>	04/10/13	9:30 AM	<input checked="" type="checkbox"/> Acceptable
Received by Lab:	C. Resutco	<i>[Signature]</i>	04/10/13	9:30 AM	<input type="checkbox"/> Other (Explain Below)

Sample Condition Additional Comments: _____

* Working days only, please consult the laboratory regarding workload. Samples received after 3:00PM will be treated as next day's samples. CASSEN's terms and conditions form a part of this contract for services. (See forms section of our website)