Bakken Petroleum: The Substance of Energy Independence

Subcommittees on Energy and Oversight

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Written Testimony

John R. Auers – Turner, Mason & Company

In the past year, considerable attention has been focused on transportation and quality issues related to Bakken crude oil. As a result of several high profile railcar incidents in the U.S. and Canada, various investigations have been launched by governmental and industry groups to better understand the safety aspects of moving Bakken crude by rail. Questions as to whether Bakken is materially different from other crude oils and if the current railroad materials classification is appropriate have been raised. Investigations are ongoing as to the cause of the railcar accidents and potential hazards to the public associated with crude oil rail movements in general. In response to these concerns, the North Dakota Petroleum Council (NDPC) commissioned a comprehensive sampling and testing program to answer questions regarding the chemical and physical composition of Bakken, issues regarding proper classification and establishment of a Bakken quality baseline. This program collected samples from seven rail terminals and 15 well sites. The crude producers that provided the well samples account for over 50% of total North Dakota (ND) production, and the rail facilities sampled represent a similar proportion of total ND crude-by-rail capacity. The sampling locations cover the entire producing region and include both “old” and “new” wells, giving a good representation of any property variations that result either from geography, production rate, or during processing and transit. At this time, we are not aware of any field-level crude oil quality assessments as extensive or as controlled as this study in the Bakken or elsewhere.

The NDPC commissioned this program to establish Bakken crude properties (Quality Characterization) and to understand if these properties pose transportation and handling risks unique to Bakken compared to other light crude oils. The results from the study are being used to help establish and maintain a Bakken quality baseline to ensure continued crude quality and consistency. The study was also used to evaluate the impact of field-operating conditions (ambient temperature, tank settling times/production rates, and field equipment operating temperatures and pressures) on Bakken qualities. These study results, together with follow-up efforts, will be used to establish “management best practices” for operating production field equipment to best meet the proposed quality specifications.

NDPC engaged Turner, Mason & Company (TM&C), to serve as project coordinator. TM&C is an internationally recognized engineering consultancy firm with over 40 years of experience in the petroleum industry (including a significant background in crude oil quality and processing). The TM&C team included engineers with extensive refining and crude characterization/evaluation experience and a chemist with over 40 years of laboratory experience in crude oil analyses who serves as Executive Director of the Crude Oil Quality Association and on the Board of the Canadian Crude Quality Technical Association. Analyses of all primary samples were conducted by SGS, a global leader in testing and inspection with over 135 years in the business. Both the local ND and U.S. Gulf Coast SGS labs participated in the sampling and testing process.

The key findings were as follows:

Quality Characterization

- Bakken crude is a light sweet crude oil with an API gravity generally between 40° and 43° and a sulfur content <0.2 wt.%. As such, it is similar to many other light sweet crude oils produced and transported in the United States.
    - As a point of reference, the Energy Information Administration (EIA) categorizes crude oil that has an API gravity between 35° and 50° and <0.3 wt.% sulfur as light sweet. Bakken falls in the middle of those ranges for both properties.
    - Overall, over 60% of the crude produced in the U.S. falls into this or lighter categories, representing over 5 million BPD.
- Although testing for sulfur, Total Acid Number (TAN) and other corrosivity-specific testing were outside the scope of this project, results from other test programs (as summarized below in Table 1) indicate that Bakken has very low sulfur and TAN properties.
- Table 1 compares key Bakken qualities to other important domestic and international crude oils:
    - Note the quality data in Table 1 for crudes other than Bakken came from sources without the extensive controls and systematic sampling procedures used in the NDPC study.

Table 1: Comparison of Crude Properties

Domestic Light Sweet Crudes	API Gravity	Sulfur (wt. %)	TAN (mg KOH)
Bakken (1) (2)	40 to 43*	0.1	< 0.1
WTI (4) (5)	37-42	0.42	0.28
LLS (2) (4)	36-40	0.39	0.4
Eagle Ford (2)	47.7	0.1	0.03
Eagle Ford Light (2)	58.8	0.04	0.02

International Crudes			
Light Sweet	**API Gravity**	**Sulfur (wt. %)**	**TAN (mg KOH)**
Brent (2) (6)	37-39	0.4	< 0.05
Medium			
Arabian Light (2)	33	1.98	< 0.1
Arabian Heavy (2)	27.7	2.99	< 0.1
Heavy			
Western Canadian Select (Heavy Sour) (3)	21.3	3.46	0.93
Dalia (High TAN) (2) (7)	23.1	0.51	1.6

Sources:	
1 - NDPC Study Data	5 - Crude Oil Quality Association
2 – Capline	6 - BP Crude Assay
3 - crudemonitor.ca	7 - ExxonMobil Crude Assay
4 - AFPM Bakken Report, 5/14/2014	* Majority of NDPC samples in this range

- The qualities of Bakken were very consistent within our sample population and throughout the supply chain – from wellhead to rail terminal to refining destination. Test results showed no evidence of "spiking" with Natural Gas Liquids (NGLs) before rail shipment.
- The test results from this study are also consistent with reported results from others, including the American Fuel & Petrochemical Manufacturers (AFPM) Bakken Report, the Pipeline and Hazardous Safety Materials Administration (PHMSA) Operation Safe Delivery Report, NDPC member-gathered data and other recent studies and presentations on the quality of Bakken crude oil.

Table 2: Bakken Quality Comparison, NDPC to AFPM and PHMSA

	NDPC Rail Avg (1)	**AFPM Report**	**PHMSA Report (5)**
API Gravity	41.7	42	Not Reported
Vapor Pressure (psi)	11.5	7.83 (2)	12.3
IBP (°F)	100.3	69.6 (3)	87.0
Light Ends (C2-C4s) (Liq. Vol. %)	4.95	3.5-11.9 (4)	4.65 (6)

Comments:

(1) Rail chosen because AFPM samples from Bakken at point of delivery; rail data from NDPC closest to direct comparison.
(2) AFPM reported RVP, NDPC reported $VPCR_4$ (D6377) at 37.8°C. AFPM also reported $VPCR_4$ done at 50°C, results 13.9-16.7 psi.
(3) 87.3 Median, Multiple tests in AFPM data, some of which can report lower than D86, which skewed average lower.
(4) AFPM report, three respondents average 3.5%, fourth had 12 samples, range 5.9-11.9%.
(5) PHMSA data from Table E, data ranging from 3/17 to 5/2, to maximize overlap with NDPC study data timeframe.
(6) PHMSA does not report isobutane, and C2-C4 results do not appear to include isobutane. By comparison, NDPC C2-C4 without isobutane was 4.37 Liq. Vol. %.

- While the test results from PHMSA's report agreed closely with the NDPC results, PHMSA did make some assertions in their Executive Summary which do not appear to be supported by their study or our findings.
    - The PHMSA report makes the statement that, "We conclude that while this product does not demonstrate the characteristics for a flammable gas, corrosive liquid or toxic material, it is more volatile than most other types of crude." No comparative data was provided in the report to support this statement, and as I note elsewhere in this testimony, the limited data available on other light crudes would not support that conclusion.

    - PHMSA also claims that a higher degree of volatility "correlates to increased ignitability and flammability." Again, no support is provided for this statement in the report. While we are aware that some groups are studying this very complex subject, we are not aware of any conclusions from those studies to date.

- During the time frame of our sampling program, Bakken had an average vapor pressure of between 11.5 and 11.8 psi, which is more than 60% below the vapor pressure threshold limit for liquids under the Hazardous Materials Regulations (43.5 psi).
    - It should be noted that the vapor pressure testing was done using the EPA approved method for crude oils (ASTM D6377), which results in readings about 1 psi higher than if the Reid Vapor Pressure (RVP) test method (ASTM D323) was used.
    - Test data from an NDPC member's rail terminal taken over a seven-month period from August 2013 through March 2014 showed RVP's in the range of 8 to 11 psi; consistent with the NDPC test results when adjusted for seasonality and test method.
    - It is difficult to compare the "typical" vapor pressure of Bakken to other crudes because of the dearth of consistent data (regarding sampling and testing methodologies) for other crudes. Most data show Bakken vapor pressure to be within 2 to 3 psi of other light sweet crudes (some higher, others lower). The AFPM Bakken Report contained the following comparison (versus key crudes), shown below in Table 3. Comparisons from other studies show similar results.

Table 3: AFPM Bakken Report, Crude Quality Comparison Table

	RVP (psi)	Vol. % Light Ends (C2-C5s)
LLS	4.18	3.0
WTI	5.90	6.1
Alberta Dilbit	7.18	7.30 wt. %
DJ Basin	7.82	8.0
Bakken	7.83	7.2
Eagle Ford	7.95	8.3
Brent	9.33	5.28 wt. %

- The flash point of Bakken is below 73°F, and the Initial Boiling Point (IBP) generally averaged between 95°F and 100°F, both of which are in the normal range for a light crude oil.
    - The data supports the current Department of Transportation (DOT) Pipeline and PHMSA classification for Bakken crude as a Class 3 Flammable Liquid (similar to other crude oils, as well as gasoline, ethanol and other materials containing light components).
    - As a result, Bakken crude oil meets all specifications for transport using existing DOT-111 tank cars.
    - This conclusion is consistent with the recent AFPM Bakken Report, which stated "Bakken crude oil does not pose risks significantly different than other crude oils or other flammable liquids authorized for rail transport. Bakken and other crude oils have been classified as flammable liquids. As noted, Bakken crude poses a lower risk than other flammable liquids authorized for transport by rail in the same specification tank cars."

- Flammable liquids fall into packing groups (PG) depending on their IBP as defined by the ASTM D86 method. The testing performed in our study highlighted the difficulty with using this test method for PG determination. The results showed significant (10°F+) variability between labs on the same sample.
    - This is because D86 was not developed for *wide boiling range* materials like crude oil, with no specifically defined lab-operating parameters specified. Therefore, different labs used different operating conditions during testing, resulting in a wide variability of values for the IBP.
- Because of the difficulty with achieving consistent IBP results, groups including API are working on recommendations for an alternative approach to determine packing group classification with a goal of obtaining DOT approval.
    - Based upon the findings of our study, the NDPC is encouraging all members to classify their BKN crude as a Class 3 PG I flammable liquid until a more definitive testing protocol is established.
- It is critical to note that the determination of PG I versus PG II has no impact on the type of rail car used or on first responder response to an incident and had no impact on any of the incidents in which Bakken was involved.
- The accuracy and precision of our test program were ratified by a series of round-robin tests between both of the SGS laboratories (Williston, ND and St. Rose, LA) used in our study and Intertek, the testing company used by PHMSA in their study.
    - The results of the round-robin testing, using identical samples (from four locations) of Bakken (tested at each of the three laboratories) showed excellent agreement on API gravity and vapor pressure.
    - Significant variance did occur in the measured IBP from the D86 testing, as noted earlier.
    - A member company conducted a similar round-robin test comparison with samples of Bakken taken from four rail cars. Duplicate samples were sent to SGS and a second laboratory, and the results of this testing also showed excellent agreement on API and vapor pressure and significant differences on D86 IBP.
- A series of side-by-side tests were performed using both the standard sealed glass jars (Boston Rounds, used for testing during the study) and Floating Piston Cylinders (FPCs) which have been suggested by some industry groups for testing vapor pressure.
    - Preliminary results proved inconclusive. Results of samples taken from the atmospheric tanks using the glass bottles came back with higher vapor pressure readings than when tested using either glass bottles or FPCs on the pressurized tank discharge.
    - Due to the requirement to sample from a pressurized tap with FPCs, there are difficulties with sampling and finding appropriate sample locations, which restricts where samples can be collected.

- These initial results, though limited, indicate that sampling with the glass bottles was at least as representative as testing with FPCs for vapor pressure, and allowed for a greater variety of sample locations with greater consistency.

Table 4 below summarizes the results from our study's sampling and testing program

- API gravity of Bakken was generally in the low 40's which falls in the range of what is considered a light crude oil.

- Vapor pressure (via ASTM D6377 at 37.8°C/100°F) was in a fairly tight range, averaging between 11.5 and 11.8 psi, with over 90% of well and 100% of rail samples measuring below 13 psi. As noted earlier, D6377 shows readings about 1 psi higher than the RVP test method (ASTM D323).

- D86 IBP showed a range of approximately 15°F on samples. All samples measured as either a PG I or II, with most of the test results close to the 95°F determination threshold. Because of the limitations of the test and variability of test conditions, the exact result varied depending on which laboratory conducted the testing.

- The light ends (C2-C4s) content of Bakken, which averaged just below 5.5 liquid volume % for all the samples and fewer than 5% for the rail samples. This is generally within 1 or 2% of other light crudes. Comprehensive data comparable to that obtained in this study for the other major Light Tight Oil (LTO) basins is not available. However, the data, which is available, indicates that Bakken light ends content is more consistent; and in many cases, lower than for most of the light crudes and condensates produced in the major LTO basins.

- It is important to note that the DOT-111 cars used to transport this crude are rated for 100 psig, and the type of car used is the same for both PG I and PG II material transport.

Table 4: NDPC Bakken Crude Sampling Data Summary

Sample Date Range	**3/25 to 4/24/2014**		
Total (152 Samples)	**Avg**	**Min**	**Max**
API Gravity	41.0	36.7	46.3
Vapor Pressure (psi)	11.7	8.9	14.4
D86 IBP (°F)	99.5 (PG II)	91.9 (PG I)	106.8 (PG II)
Light Ends (C2-C4s)	5.45	3.33	9.30
Rail (49 Samples)	**Avg**	**Min**	**Max**
API Gravity	41.7	39.2	44.0
Vapor Pressure (psi)	11.5	9.6	12.9
D86 IBP (°F)	100.3 (PG II)	96.7 (PG II)	104.1 (PG II)
Light Ends (C2-C4s)	4.95	3.91	6.44
Well (103 Samples)	**Avg**	**Min**	**Max**
API Gravity	40.6	36.7	46.3
Vapor Pressure (psi)	11.8	8.9	14.4
D86 IBP (°F)	99.1 (PG II)	91.9 (PG I)	106.8 (PG II)
Light Ends (C2-C4s)	5.69	3.33	9.30

The results indicate that the well-to-well quality of Bakken is very consistent. Testing across the geographic area showed very limited geographical variation in key properties such as API, vapor pressure and light ends content. Data provided by one of the NDPC member companies (which involved testing over an eight-month period) showed that while there was some seasonality in vapor pressure, it was not significant (3 psi lower in summer months vs. winter months) and it agreed very closely with the AFPM seasonality data. The data was also consistent with the NDPC test results during the period when the sampling overlapped.

Bakken quality, throughout the supply chain in our sample pool, was also consistent. There was no evidence of “spiking” of Bakken crude with NGLs between the well and rail terminals, with rail terminals showing less variation and tighter averages than well-readings. This was expected, given that regional rail facilities receive oil from many wells. Additionally, limited sampling at both the rail terminal and destination refinery showed no significant weathering or off-gassing of light ends in transit.

Operating Conditions/Impact on Bakken Quality

In addition to characterizing the quality of Bakken crude, our study looked at the impact that well site operating conditions have on the quality. These conditions include ambient temperature, production volume flow rates/field tank settling time, vapor capture status and field equipment operating parameters such as separator and treater temperatures and pressures. All of these measurements were recorded during the sampling program and have been correlated to determine how they impact test results. Based on this analysis, we offer the following observations and conclusions:

- The samples were gathered during the spring season (late March to late April) and ambient temperatures varied from a low of 10°F to a high of 65°F (average of about 34°F).
    - Vapor pressure will vary by season with lower vapor pressures (lower levels of dissolved light ends) in the hotter summer months and higher vapor pressures (higher levels of dissolved light ends) in the colder winter months. This was confirmed by the member-contributed data referred to earlier in this section (and included later in this report).
    - The results during this sampling program were in the intermediate range due to the mid range ambient temperatures experienced during sampling.
    - Although the temperature range was limited, vapor pressure levels did correlate with temperatures (consistent with the more extensive member contributed data and the AFPM data), and with higher measured vapor pressure for crude sampled with lower ambient temperatures.
- While the companies operating in the Bakken that participated in our sampling program use a variety of well-site production equipment and operating conditions (production rates, equipment operating pressures and temperatures) which varied across the study, key crude qualities from our study were distributed across a fairly narrow range.
    - The data consistency indicates that field equipment is limited in its ability to significantly impact vapor pressure and light ends content.
    - This is consistent with the expected capabilities of the equipment.
    - The field equipment is designed to separate gas, remove water and break emulsions to prepare crude for transport, and not remove significant levels of dissolved light ends from the crude.

- Despite the limitations of the field equipment, the data did show that the content of some of the lighter components, specifically ethane and propane, was reduced in a measureable way by running the equipment at higher temperatures.
    - The difference between running cold (50°F) and running at close to the maximum practical temperature (150°F) resulted in an average reduction of 0.13 liquid vol. % ethane and 0.25 liquid vol. % propane, and about 0.40 liquid vol. % of total light ends reduction.
    - Total ethane levels were almost universally below 0.20 liquid vol. % (and often closer to 0.10 liquid vol. %) when treaters were run at temperatures above 140°F, compared to levels averaging around 0.30 liquid vol. % (and as high as 0.40%) when temperatures were less than 100°F.
    - It is important to note that true "plant tests" were not conducted where the field equipment temperatures and pressures were varied systematically at individual well sites, but rather results correlated across all samples at all locations.
- Production rates were also obtained at the time of sampling in an effort to determine whether higher flowing wells retained more light ends and had a higher vapor pressure than lower flowing wells where there was more opportunity to "weather" off the light components.
    - The data from the study showed very limited correlation between production rates and vapor pressure.
    - There was also little difference observed in vapor pressure between samples which were obtained from wells directly connected to a gathering system (no settling time) versus those obtained from stock tanks (where there was an opportunity for settling).
    - As with the analysis of treater conditions impact on crude quality, the fact that this analysis was not done under systematic "plant test" conditions does not confirm that there is not some impact on vapor pressure, but rather that the impact is likely limited.

Conclusions and Recommended Action Steps

- Bakken is a light sweet crude oil with very consistent properties throughout the entire production basin, and the properties measured meet all the requirements of 49 CFR 171-180 for safe transport by rail or truck.

Based on the results of this study, the NDPC has developed a set of Field Operations Recommended Best Practices. These cover the operation of the field treating equipment, Bakken crude oil quality, testing procedures and shipping classification, and are detailed in Table 5 below:

Table 5: BKN Field Operations Recommended Best Practices

Field Treating Equipment (In an effort to minimize light ends in crude oil presented for market)

- Design and operate all equipment within manufacturers recommended operating limits.
- Operate Gas/Liquid Separator (if utilized) at the lowest pressure to accommodate gas sales and fluid delivery to the Emulsion Separator/Heater Treater.
- Operate Emulsion Separator/Heater Treater pressure to the lowest operating pressure to safely accommodate gas sales and fluid delivery to the production tank battery.
- Maintain all fired treating equipment (Emulsion Heater Treater, etc.) temperature between 90° and 120° F+ year round.
- Provide maximum tank settling time possible prior to shipment.
- Reduce stock tank pressure to lowest pressure possible to maintain vapor collection equipment (engineered flare, vapor recovery, etc.) operational integrity.

Typical **BKN *** Specifications (ranges reflect expected seasonality)

	Range	Typical
• API Gravity (hydrometer at 60°F)	35° to 45°	42°
• Vapor Pressure (ASTM D6377 @ 100°F)	8 to 15 psi	11.5 psi
• Initial Boiling Point (ASTM D86)	90°F to 105°F	95°F
• Sulfur	<0.3%	0.15%
• H_2S	<10 ppm	<1 ppm
• Light Ends (C2 – C4s)	3% to 9%	5%

***BKN** refers to light sweet crude aggregated at rail and pipeline terminals within the Williston Basin. This crude is predominantly sourced from the Bakken common source of supply, but also includes legacy production from various other producing formations located within the proximity of the Bakken field. **BKN** does not include nonstabilized condensate recovered from wet gas gathering pipelines or from product derived outside the U.S. Williston Basin. Individual well values may be higher or lower than the aggregated values observed at the rail terminals.

Testing Procedures

- Well Site Operators/Purchasers – Prior to each custody transfer or LACT EOM
  - API gravity corrected to 60° F using hydrometer
  - Basic Sediment & Water (BS&W) by field centrifugal grind-out
  - Spot test vapor pressure pending available field testing equipment
- Rail/Pipeline Terminal Operators
  - Test each unit train loading or tank shipment batch
    - API gravity corrected to 60° F using hydrometer
    - BS&W by field centrifugal grind-out
  - Test at least midmonth and EOM
    - ASTM D6377 @100° F vapor pressure using certified laboratory
- DOT PHMSA Hazmat Shipping Category
  - Flammable Liquid Category 3
  - Packing Group I**

** PG I is recommended even though the majority of samples tested for the study would fall within specifications for PG II. The margin of error for the test methodology can result in different labs testing the same sample with values meeting both PGs. PG I has the more stringent standards and is therefore recommended to avoid further confusion.

Testing Procedures (cont.)

- Other recommended procedures
  - DO NOT deliver fluid recovered from gas pipe lines (a.k.a. “pigging operations”) to crude oil sales system unless processed by stabilization unit capable of lowering vapor pressure below 10 psi at 100° F.
  - DO NOT blend non-Williston Basin crude oils into the BKN common stream.
  - DO NOT blend plant liquids (plant condensates, pentanes, butanes or propane) into the BKN common stream.