A Survey of Bakken Crude Oil Characteristics Assembled

For the U.S. Department of Transportation

Submitted by

American Fuel & Petrochemical Manufacturers

Prepared by

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Executive Summary

Recent incidents in the U.S. and Canada involving the transport of Bakken crude oil originating in North Dakota has focused considerable attention on the transportation of Bakken crude oil by rail. Questions have been raised as to whether Bakken crude oils pose substantially different risks than crude oils that have traditionally been transported. At the request of the Department of Transportation (DOT), the American Fuel & Petrochemical Manufacturers (AFPM) conducted a survey of its members to address questions posed by DOT and developed this report of its findings. In addition to obtaining responses to the questions DOT raised, as part of its survey, AFPM also collected data stemming from analysis of approximately 1400 samples of Bakken crude oil in order to better understand its properties.

This report assembles AFPM member responses to questions posed by DOT and provides summary data on Bakken crude oil characteristics and hazards based on the sample information collected. The results show that Bakken crude oil may appropriately be classified as a flammable liquid based on DOT and international transportation requirements.[1] Comparison of assay data on Bakken crude oil with data from non-Bakken crude oils indicates that Bakken crude oil is within the norm with respect to the hazard characteristics of a light crude oil. While Bakken crude (and other light crudes) may contain higher amounts of dissolved flammable gases compared to some heavy crude oils, the percentage of dissolved gases would not cause Bakken crude to be transported under a DOT hazard class other than Class 3 Flammable Liquid and does not support the need to create a new DOT classification for rail transportation. Flammable gas content correlates with vapor pressure. The maximum vapor pressure observed based on data collected was 61% below the vapor pressure threshold limit for liquids under the HMR; demonstrating that Bakken crude oil is properly classified as a flammable liquid. With one exception, hydrogen sulfide concentrations were found to be extremely low – below the Short Term Exposure Limits for workers established by OSHA regulations. In the exceptional case, concentrations were substantially higher. Where they exist, high hydrogen sulfide concentrations are addressed under existing transportation and workplace safety regulatory provisions without affect to rail tank car authorizations. Data and experience indicate there to be no basis for classifying Bakken crude oil as having a corrosivity risk as defined by DOT Hazardous Materials Regulations.[2]

The information provided confirms that 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. Measured tank car pressures show that even the older DOT 111's authorized to

[1] The United Nations Recommendations on the Transport of Dangerous Goods form the basis for DOT regulations and regulations used widely throughout the world.
[2] Title 49 of the Code of Federal Regulations Parts 105 to 180.

transport Bakken crude oil are built with a wide margin of safety relative to the pressures that rail tanks may experience when transporting Bakken crude oil.

Survey results are summarized below. Bakken crude oil currently is transported in compliance with the HMR as a Class 3 flammable Liquid in either Packing Group I, II, or III. In conclusion, there is no identifiable basis for regulating Bakken crude differently than other flammable liquids regulated by the DOT Hazardous Materials Regulations.

Summary Table on Bakken Crude Oil Characteristics Evaluated in AFPM's Survey

Characteristic	Reported Values	Hazmat Transportation Regulatory Implications
Flashpoint	Range: -59°C to 50°C	Bakken crude oils meet the criteria for Packing Group I, II, or III flammable liquids or as combustible liquids[3]
Initial Boiling Point	Range: 2.2°C to 66.9°C	Bakken crude oils with an initial boiling point of 35 °C or less meet criteria for Packing Group I flammable liquids; others for Packing Group II or III flammable liquids or combustible liquids according to flashpoint
Vapor Pressure at 50°C	Maximum: 16.72 psia	All Bakken crude oils have a vapor pressure below 43 psia at 50°C and must be transported as liquids
Reid Vapor Pressure at 38°C	Maximum:15.4 psia	Not used by the regulations; confirm the vapor pressure at 50°C is well below the above 43psia limit and Bakken crude oils must be transported as liquids.
Rail tank car pressures on delivery	Maximum:11.3 psig	Demonstrates that Bakken crude may be safely transported in DOT specification 111 tank cars [4]
Flammable gas content	Maximum:12.0 liquid volume %	None; with the vapor pressures of all Bakken crudes oils examined not exceeding a vapor pressure of 43 psia at 50°C, all Bakken crude oils examined must be transported as liquids
Hydrogen sulfide content in the vapor space	Most reported H_2S concentrations were below the OSHA STEL; one reported a maximum level of 23000 ppm	None when low values are experienced; additional hazard communication to warn of the presence of H_2S when inhalation hazard levels are encountered[5]
Corrosivity	NACE B+ or B++	Data and experience indicate that Bakken crude oil does not corrode steel at a rate of ¼ inch per year or more so that Bakken crude oil is not a corrosive liquid

[3] *Note* the Bakken crude data submitted included only one sample that qualified as a combustible liquid, which has a lower risk than other flammable liquids.

[4] §179.201-1 provides summary specifications for DOT-111 rail tank cars. Earlier DOT 111's were designed to a 240 psig burst pressure whereas later designs are designed to a minimum burst pressure of 500 psig. Based on §179.15(b)(2)(ii) the minimum pressure relief valve settings for tank cars with a minimum burst pressure of 240 psig is 35 psig and for 500 psig designs the minimum setting is 75 psig.

[5] See §172.327.

I. Introduction

The American Fuel & Petrochemical Manufacturers (AFPM) is an industry association representing virtually all of the petroleum refiners and petrochemical manufacturers throughout the United States. The fuel and petrochemical manufacturing industries have a strong commitment to safety as well as environmental protection, and strive for opportunities to enhance safety and environmental protection. AFPM members depend upon a plentiful, affordable supply of crude oil as a feedstock for the transportation fuels and petrochemicals that they manufacture. Approximately 11 percent of the crude oil processed by AFPM members is transported by rail.

As manufacturers, AFPM members acquire crude oils from multiple sources, including crude oil produced from the Bakken formation. Based on concerns expressed by the U.S. Department of Transportation (DOT) over the properties of Bakken crude oil being transported by rail, AFPM, at DOT's request, conducted a survey of its members in an effort to characterize various hazard characteristics that could be relevant to the transportation of Bakken crude oils. For comparison purposes, the properties of crude oils from other fields were also considered.

Bakken crude oil is derived primarily from northwestern North Dakota and to a lesser extent northeastern Montana, and the bordering Canadian provinces of Manitoba and Saskatchewan. Due to the lack of pipeline infrastructure, Bakken crude oil is transported extensively by rail. The data submitted in response to the survey demonstrates that Bakken crude oil is properly transported in accordance with the DOT Hazardous Materials Regulations (HMR) as UN1267 Petroleum Crude Oil, or NA1993 Combustible Liquid, NOS.

Survey Scope

The initial questions posed to AFPM by DOT's Pipeline and Hazardous Materials Safety Administration (PHMSA) on January 29 are attached in Appendix 1 to this report. PHMSA personnel in a regional office posed additional questions to AFPM members and these are attached in Appendix 2. These two sets of questions formed the basis for the survey conducted by AFPM. More recently, the experts from Canada and the United States to the United Nations Subcommittee of Experts on the Transport of Dangerous Goods submitted a formal document noting recent rail transport incidents involving Bakken crude oil and soliciting the input of the Subcommittee as to whether crude oil such as Bakken crude oil derived from fracking operations posed a different degree of risk than other crude oils.[6] To the extent possible this report also responds to questions raised in the UN paper.

This report compiles information provided by 17 AFPM members who participated in the survey. Data analysis focused on Bakken crude oil as transported. Bakken data stems from sampling at loading points at well head locations, intermediate collection facilities (distribution

[6] A copy of the UN Paper is reprinted in Appendix 3.

centers) at which crude oil may be loaded into rail tank cars and at refinery locations taking receipt of crude oil after a rail journey. Data on approximately 1400 samples of Bakken crude oil was taken into account.

II. Discussions on Transportation Considerations – Regulatory, Practice and Hazard Characteristics

While PHMSA's Bakken Blitz data collection is ongoing, PHMSA staff has suggested that Bakken crude oil is different from other crudes oils that have traditionally been transported by rail in the United States. The Canada/U.S. UN paper reiterates this opinion concerning Bakken crude oil stating, "[t]his mostly 'younger' crude is being found to contain significantly higher 'light ends' than what has been traditionally transported as UN 1267." Again referring to crude oils like Bakken crude oil, the UN paper goes on to suggest, "lighter crude oil with a higher quantity of dissolved flammable gases pose a significantly different risk than heavier crude oils that do not have such a high constituency of more volatile components." Against this background, it may be instructive to first examine some relevant regulatory requirements, related crude oil hazard characteristics, and transport practices, particularly as they relate to Bakken crude oil.

Definitions of gas and liquid.[7] The HMR base the definition of a gas on whether a substance is a gas at 20°C (68°F). Substances with a vapor pressure of more than 300 kPa (43.5 psia) at 50°C (122°F) are also considered as gases irrespective of whether any liquid is still present at that temperature. Substances that have a vapor pressure of not more 300 kPa (43.5 psia) at 50°C (122°F) and with a melting point at or below 20°C (68°F) are generally considered liquids. Crude oil, including Bakken crude oil, is properly classified as a liquid – irrespective of light end concentration – provided its vapor pressure is not more than 300 kPa (43.5 psia) at 50°C (122°F). The AFPM survey confirms that vapor pressures of Bakken crude oil are well below the 300 kPa at 50°C (122°F) limit and are properly transported as liquids under the HMR.

Reid Vapor Pressure (RVP). Reid vapor pressure is a common measure of a substance's vapor pressure at 100°F (38°C). The RVP of crude oil increases with the increasing presence of flammable gases and other volatile flammable liquid components (e.g., pentanes).

Up until 1990, prior to harmonization of the HMR with international regulations, the HMR used RVP in place of the 300 kPa at 50°C (122°F) criterion for differentiating between a liquid and a gas.[8] A substance with an RVP of 40 psia or less was regarded as a liquid. In addition, earlier editions used flashpoint and RVP as a basis for identifying authorized packagings, including authorized rail tank cars, for various flammable liquids. Then, §173.119 differentiated substances with an RVP of 16 psia or less from more hazardous substances with RVP's between

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[7] *See* 49 CFR § 171.8.
[8] 49 CFR §173.119 (1990 ed.).

16 and 27 psia and 27 and 40 psia; and used an RVP of 40 psia as the threshold for use of DOT specification 111 tank cars. It is noteworthy that Bakken crude oil RVP values obtained in this survey were all less than 16 psia so that the corresponding crude oils would all have been subject to earlier HMR packaging requirements appropriate for the two prior lowest hazard flammable liquid categories.

RVP continues to be used by other regulatory agencies and the petroleum industry. For example, U.S Coast Guard (USCG) regulations for tank ships and tank barges still use a 40 psia RVP criterion for differentiating between liquids and gases in the case of petroleum products, including crude oils. The USCG regulations permit substances to be transported in integral tanks (i.e., gravity tanks not designed for any appreciable pressure) when regarded as liquids (i.e., RVP of 40 psia or less).[9]

Though no longer used in the HMR, the considerable information on the RVP of Bakken crudes serves to provide insight into the characteristics of crude oils derived from the Bakken formation. The current regulatory limit of 300 kPa at 50^{o}C is only marginally different from RVP in the case of crude oils so that RVP values may be deemed a close approximation of the vapor pressure at 50^{o}C (122^{o}F).

Degree of hazard. The HMR vary the stringency of requirements according to the degree of risk various substances pose in transportation. Many hazards, including the flammability hazard of liquids, are subdivided into three risk levels:

Packing Group I – encompasses substances regarded as posing a high hazard level;
Packing Group II – encompasses substances regarded as posing a medium hazard level; and
Packing Group III – encompasses substances regarded as posing a low hazard level.

Packing Group as it pertains to rail transport. While Packing Group is commonly used in the HMR for purposes of tiering the severity of regulatory requirements, in the case of rail transport of crude oil, it should be noted that DOT 111 rail tank cars are authorized for transporting Packing Group I, II and III crude oils under UN1267.[10] DOT 111's are widely used for transporting Bakken crude oil. While the HMR also authorize AAR Class 206 rail tank cars for Packing Groups II and III crude oil, these are legacy tank cars with few remaining in service. As such, Packing Group, in practice, has little to no impact on the integrity of rail tank cars used in transporting Bakken crude oil since DOT specification 111 tank cars are in common usage.[11]

DOT regulations and publications suggest that Packing Group is a secondary consideration in the case of emergency response. HMR placarding and rail tank car markings requirements, which are intended to communicate essential emergency response information, to emergency responders in the event of an accident or incident, do not communicate the Packing Group of the

[9] *See* 46 CFR §§ 30.10-22 (definition of a flammable liquid) and 30.10-39 (definition of a liquefied flammable gas).
[10] *See* 49 CFR §§ 173.242 and 173.243.
[11] For combustible liquids AAR 203W (less than 100) and 211W (less than 1100) tanks are also authorized.

hazmat involved. Further, the 2012 Emergency Response Guidebook (ERG)[12] does not take Packing Group into account when advising emergency responders on immediate first response measures.

The HMR require shippers to include the Packing Groups of hazardous materials on shipping papers and for rail transport this second level information for crude oil and other hazardous materials is available to emergency responders by accessing the train consist.[13] Bakken crude is described on shipping papers (or the train consist) depending on Packing Group in the following concise well recognized format:

- UN1267, Petroleum crude oil, 3, I;
- UN1267, Petroleum crude oil, 3, II; or
- UN1267, Petroleum crude oil, 3, III.

When Bakken crude oil is transported in DOT 111 rail tank cars, as is common practice, the difference in shipping paper descriptions is the only regulatory difference distinguishing Packing Group I, II or III Bakken crude oils as they are transported by rail.

Flammability. Flammable gases and vapors will ignite when they are mixed with air in certain concentration ranges. The lowest temperature at which flammable liquids produce vapor in sufficient amounts to support combustion is termed the liquid's *flashpoint*.

Under DOT and international regulations, a flammable liquid is a liquid that has a flashpoint of less than or equal to 60°C (140°F). Flammable liquids with a flashpoint of 23°C (73°F) or less are assigned to either Packing Group I or II. In essence, the flashpoint limits of 23°C (73°F) and 60°C (140°F) for flammable liquids indicate whether a substance has:

- Potential of producing a flammable vapor under moderate ambient temperature conditions – i.e., 23°C (73°F); or
- Potential of producing a flammable vapor under the most extreme ambient temperature conditions – i.e., 60°C (140°F).

Under the HMR, a flammable liquid with a flashpoint in the range of 38°C (100°F) and 60°C (140°F) may also be regarded as a combustible liquid, reflecting that such substances have a lower risk of igniting. Combustible liquids also include liquids with a flashpoint up to 93°C (200°F).

Except for classification under the HMR, flashpoint is not commonly used to characterize crude oil. Testing for flashpoint is an inherently dangerous test to conduct even under controlled laboratory conditions. Given the specific threshold values in the HMR, measurement of an exact

[12] The ERG is periodically prepared and published jointly by DOT and the governments of Canada and Mexico. Registration fees collected from hazmat shippers and carriers in accordance with 49 CFR Subpart G support its wide distribution to emergency responders in the U.S.
[13] *See* 49 CFR §§ 172.202(a) and 174.26.

flashpoint value is not required. For compliance with the HMR, it is important to know what range of values the flashpoint of a particular crude oil falls into (e.g.; 23^{o}C or less) – not the specific flashpoint value. For this purpose, approximation methods may be used (e.g.; chromatography or calculation methods). This may be common practice in the case of routine screening of crude oil shipments. Test methods identified by the HMR are typically not valid for substances below -30^{o}C (-22^{o}F); and approximation methods may have been used in producing some of the flashpoint data discussed in this report.

While there is no regulatory limit on how low the flashpoint of a flammable liquid may be, diethyl ether, a Packing Group I flammable liquid transported as a pure substance, has a flashpoint of -45^{o}C (-49^{o}F).

Initial boiling point. The HMR and international regulations use initial boiling point as a classification criteria. Boiling point is considered indicative of a substance's volatility or its propensity to form flammable vapor plumes in air. Plume formation could occur after a spill of a flammable liquid when a fire is not involved. Increasing volatility leads to the formation of larger flammable vapor plumes. A lower boiling point generally implies increased volatility. As such, boiling point is used to evaluate the degree of risk a flammable liquid poses. The larger the flammable vapor plume a flammable liquid is capable of forming when spilled, the more dangerous it is considered to be, since the size of the plume affects the probability that flammable vapors will reach an ignition source and ignite. Predicting the size of a plume a particular liquid produces involves complex calculations accounting for ambient conditions and many other properties of a substance. Since boiling point is widely available, it is used as an approximation for gauging a substance's volatility. The HMR use *initial boiling point* as the basis for a differentiating between substances that have a Packing Group I high hazard risk (i.e., an initial boiling point of less than 35^{o}C (95^{o}F)) or a Packing Group II medium hazard risk.

Pure substances have a single boiling point and boil off completely at one temperature. Mixtures of flammable liquids made up of various components, like crude oil, boil over a temperature range. The more volatile components (e.g., dissolved gases in the case of crude oils) will boil off at the initial boiling point leaving less volatile components with higher boiling points in the liquid. Increasingly higher temperatures are required to boil off remaining components. Subsequent less volatile and less dangerous (from a flammability perspective) fractions of a liquid mixture may not boil off until significantly higher temperatures are reached. An assay of a Bakken crude oil indicates a boiling point range spanning approximately 500^{o}C. From a flammability/volatility perspective, in comparing a pure substance with a flammable liquid mixture with the same initial boiling point, the pure substance is more volatile and more dangerous.

DOT flammable liquid classification criteria. The HMR and international regulations classify flammable liquids into three Packing Groups as follows:

Packing Group	Flash point (closed-cup)	Initial boiling point
I		≤35 °C (95 °F)
II	<23 °C (73 °F)	>35 °C (95 °F)
III	≥23 °C, ≤60 °C (≥73 °F, ≤140 °F)	>35 °C (95 °F)

Emergency Response. An important function of the HMR is to provide hazard information to emergency responders in the event of an accident or incident involving a hazardous material in transportation. The HMR hazard classification requirements result in the assignment a hazard class (e.g., flammable liquid), assignment of a UN number and proper shipping name and assignment of Packing Group. These determinations in turn lead to requirements for labeling and placarding to pictorially communicate the various HMR hazards, package markings to convey the UN number and proper shipping name, and shipping paper requirements providing additional information on the details of a hazardous material shipment.

The 2012 Emergency Response Guidebook (ERG) is intended to supplement hazard communication information provided on packages and shipping papers. It is intended for use by emergency responders first arriving on the scene of an accident or incident. First responders include law enforcement personnel and fire department personnel – both professionals and volunteers. DOT distributes the ERG widely throughout the United States with the objective of making it available to every potential first responder. The frequency of hazardous materials accidents and incidents is rare so that on average a first responder is expected to encounter less than one incident in a career. As such information must be basic and understandable to those who have a low probability of encountering a hazardous materials accident or incident.

The ERG serves this purpose. Through the UN number or proper shipping name of a substance, a first responder is able to access instructions on what steps to take upon arrival at the scene of an accident or incident. For crude oil assigned to UN 1267 Petroleum crude oil, irrespective of Packing Group, or crude oil meeting combustible liquid criteria and transported under NA 1993 Combustible liquid, NOS, guide page 128 of the ERG provides a first responder with the appropriate information (see Appendix 5). In this respect, it is important to note that the range of crude oils subject to the HMR (i.e., crude oils of Packing Groups I, II and III and combustible liquid crude oils) are addressed by one set of instructions made available to first responders. The same guide page is applicable to many other flammable liquids independent of the degree of hazard.

Flammable gases dissolved in liquids. Gases typically dissolve to some degree in liquids. For a given temperature, the amount of gas that dissolves in a liquid is directly proportional to the partial pressure of the gas in equilibrium with the liquid. The amount of gas that can dissolve in a liquid increases with pressure and decreasing temperature. For this reason, soda in a bottle bubbles when the top is removed as carbon dioxide held in the liquid is released as a gas because the bottle pressure no longer holds the carbon dioxide in the liquid. The same happens with crude oil where flammable gases such as methane, ethane, propane and butane, held in solution under high pressure underground, are released as the pressure is decreased when it is brought to the surface and stored. If stored at a low temperature, crude oil will retain more gas than if stored at a higher temperature.

Crude oil taken from the wellhead and placed in a stabilization tank continues to release dissolved gases until an equilibrium concentration between the gas dissolved in the crude oil and the concentration of the gas in the tank vapor space is reached.

The DOT definition of a gas places a regulatory limit on the amount of flammable gas that may be held in crude oil in transportation. If a crude oil had a vapor pressure in excess of 300 kPa at $50^{o}C$ ($122^{o}F$) due to a high dissolved gas concentration, it would be regarded as a gas and not as a liquid.

In some cases the HMR explicitly permit some quantities of certain gases to be transported in liquids. For example, up to 30% ethylene oxide (a toxic and flammable gas) may be transported in propylene oxide (a liquid) under UN 2983 Ethylene oxide and propylene oxide mixtures.

Hydrogen sulfide. In a pure form hydrogen sulfide is a gas and is regulated as a toxic and flammable gas under the HMR and OSHA regulations. Crude oil commonly contains some amount of sulfur. It may be present in hydrocarbon molecules (e.g., mercaptans) or as hydrogen sulfide dissolved in the liquid. The chemical/thermal and biological breakdown of the sulfur bearing hydrocarbon molecules in crude oil, as it is brought to the surface and is stored, may lead to increased evolution of hydrogen sulfide gas in crude oil liquid and vapor.

When a crude oil contains concentrations of hydrogen sulfide at levels that may present an inhalation hazard, the HMR require communication of its presence. Bakken crude oil is generally considered a sweet crude and the survey data confirm that sulfur and hydrogen sulfide concentrations are normally low. However, exceptions were noted in the case of one respondent.

Light crude oils. Light crude oils are generally regarded as those crude oils with an API gravity of 37 degrees or more. API gravity varies inversely with specific gravity so that increasing API gravity values reflect decreasing specific gravity or density. Light crudes tend to have higher concentrations of light ends (i.e., methane, ethane, propane, butanes and pentanes). The presence of increasing amounts of dissolved gases and other light ends (i.e., pentanes) has the effect of increasing the crude oil's vapor pressure, lowering its flashpoint and lowering its initial boiling point. Light crude oils may qualify as Packing Group I, II or III flammable liquids under the

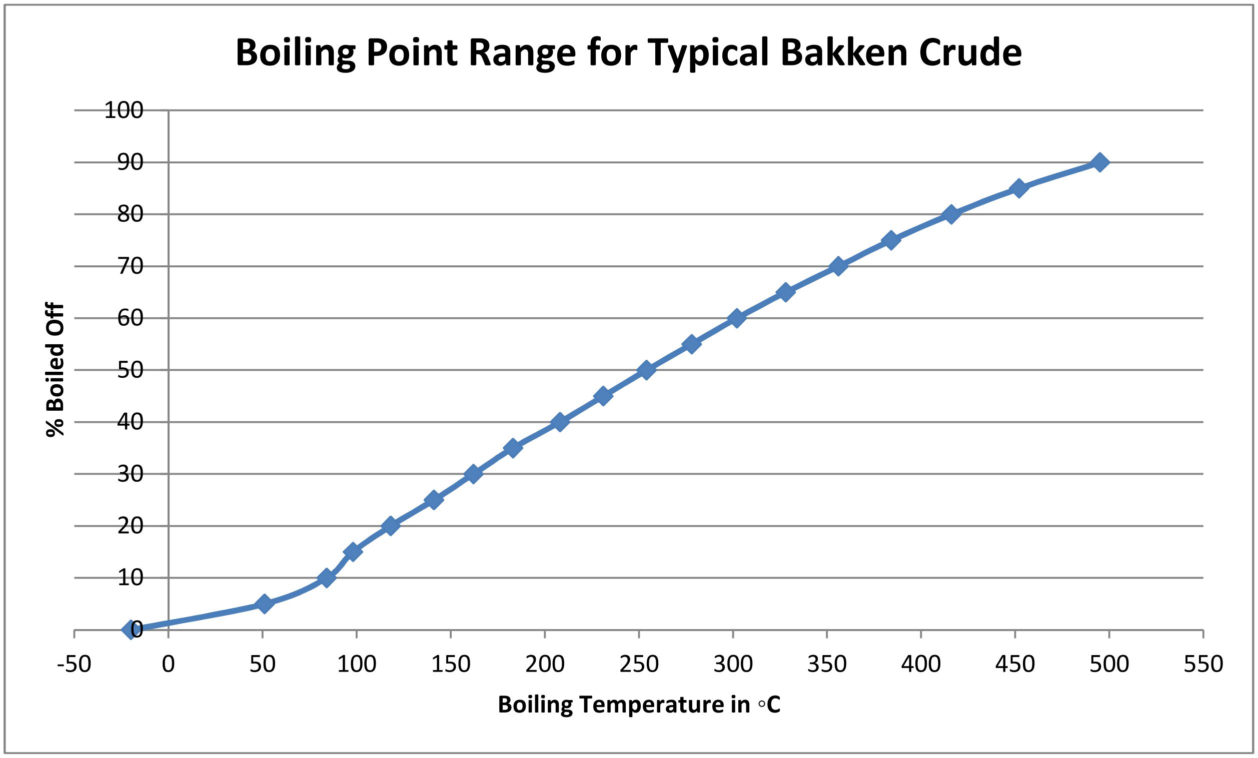
HMR depending on properties of the specific crude oil. Some may be transported as combustible liquids. Light crude oils are common throughout the world. Bakken crude oil is regarded as a light crude oil.

Bakken crude oil. Bakken crude oil, like other crude oils, consists of a range of primarily hydrocarbon gases and liquids. The table below illustrates the composition of a Bakken crude oil sampled at a distribution center prior to loading for rail transportation. The table also provides the HMR classification for each component. Division 2.1 refers to the HMR flammable gas classification and Class 3 refers to the HMR flammable liquid classification. The particular Bakken crude oil sample depicted in the sample below had an RVP of 7.6 psia.[14]

Hydrocarbon gas	Concentration in Liquid Volume %	DOT Classification
Methane	<0.01	Div. 2.1 Gas
Ethane	0.05	Div. 2.1 Gas
Propane	0.80	Div. 2.1 Gas
Iso-Butane	0.46	Div. 2.1 Gas
N- Butane	2.36	Div. 2.1 Gas
Total Gas	3.67	
Neopentane	<0.01	Class3; PG I
Iso-Pentane	1.33	Class 3; PG I
N-Pentane	2.36	Class 3; PG II
Hexanes	4.10	Class 3; PG II
Heptanes Plus	88.56	Varies Class 3; PG II to combustible liquid to non-regulated
Benzenes	0.08	Class 3; PG II

For the same crude oil, the figure below provides the boiling point range. Note that the boiling point temperature progressively increases after the more volatile components are boiled off.

[14] Among assays of Bakken crude oil, 7.6 psia is a normal RVP value.



[15]

Consideration of flashpoint and boiling point data for hydrocarbons suggests that, for the crude oil illustrated, when 40% of the crude oil is boiled off, the remainder would not be regulated as a flammable liquid.[16] As boiling continues beyond the 40% level, the remaining liquid would transition from a combustible liquid to a non-regulated substance. All else being equal, a pure flammable liquid with a boiling point comparable to the initial boiling point of the example crude oil would produce a flammable vapor plume 2.5 times larger than the example crude.[17] While a rough comparison, it illustrates that pure substances may be considerably more volatile than flammable liquid mixtures with identical initial boiling points.

The range of boiling points also suggests that in accident conditions where a tank is engulfed in flames, considerably more heat would be required to boil off the example crude oil than would be required of a pure substance with the same IBP. Consequently, based this and other factors, pressure buildup within a tank containing the example crude oil would be expected to be more gradual than that for a pure substance.

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[15] IBP values in this chart where based on ASTM 5307, a capillary chromatography method, producing lower values as compared to IBP data from samples provided which were based largely on ASTM D 86 – a method referenced in the HMR.

[16] Estimated based on the properties of n-dodecane, a C-12 hydrocarbon with a flashpoint of 71°C and a boiling point of 216°C, which is not subject to the DOT HMR as a flammable liquid. Crude oil compositions with a boiling point of 216°C or higher were assumed to not qualify as flammable liquids with a flashpoint less than 60°C.

[17] Some examples of other Class 3 Flammable Liquids that are transported in DOT 111's with a higher risk profile than Bakken crude would include: diethyl ether, acrylonitrile, and ethyl mercaptan.

Crude oil processing. When crude oil is extracted, it is typically processed to remove water and entrained gases, and stored in a tank prior to transportation. Processing, settling time in storage tanks and ambient temperature conditions all influence the extent to which light ends including gases are released from crude oil before it is transported.

III. Survey Results

A. Testing Used to Evaluate Bakken Crude Oils

As a Class 3 flammable liquid or a combustible liquid under the HMR, Bakken crude oil is subject to evaluation of its flashpoint and initial boiling point for classification purposes in accordance with the HMR. Other tests evaluating vapor pressure, flammable gas content, hydrogen sulfide content and corrosivity are also employed by industry and provide additional information relative to the hazards of crude oil.

Tests are carried out on crude oil samples taken at multiple locations along the distribution chain as it moves from the production point at a well to a refinery destination. Samples may be taken and evaluated at the well head, at gathering stations, at rail loading facilities, at pipeline facilities and when it is received at the refinery. Survey responses include data resulting from testing by AFPM members or independent laboratories (e.g. assays).[18] Data considered relevant for purposes of this survey was limited to data characterizing crude oil “in transportation,” – ranging from data on samples taken at the well head location at the point of loading for transportation to data from samples taken where transportation ended at the refinery gate.

Members generally found variations in properties of specific crude oils to be minimal as these crude oils moved through the distribution chain. Summary data provided in the survey aggregates data obtained for samples taken along the distribution chain. A number of members noted seasonal variations in some properties of Bakken crude oils. The variations may be attributable to higher retention of flammable gases in crude oils in winter owing to lower ambient temperatures.

B. Test Methods Used to Characterize the Hazards of Crude Oil

PHMSA requested information on test methods used to characterize crude oil. The test methods used to evaluate selected characteristics are provided in Appendix 4.

[18] Crude oil assays are detailed evaluations of crude oils that are commonly performed for commercial non-regulatory purposes. They may be used to define crude oil purchased by a refiner from a producer. The values reported in an assay reflect the properties of a specific sample. They are intended to represent characteristics of crude oils to be purchased and do not normally account for variations that may be identified among multiple samples. For example, higher RVP values for Bakken crude oil are noted in this survey for other samples. In addition, data from more than one assay was used in this report. Even though the data in assays are not normally used for regulatory compliance purposes, consideration of assay data was instructive for purposes of this survey given the detailed information they provide.

C. Reported Information and Test Results - Discussion and Range

The following information on Bakken crude oil is based on responses from AFPM members and data provided on approximately 1400 samples of Bakken crude oils.[19] The data included data points on specific characteristics as follows:

Flash Point: 77 data points;
Initial Boiling Point: 275 data points;
RVP: 807 data points;
Rail Tank Car Pressure (PSIG): 387 data points;
Total C1-C4: 18 data points;
H_2S in Liquid: 37 data points;
H_2S in Vapor: 535 data points; and
Corrosivity to metal: 7 data points.[20]

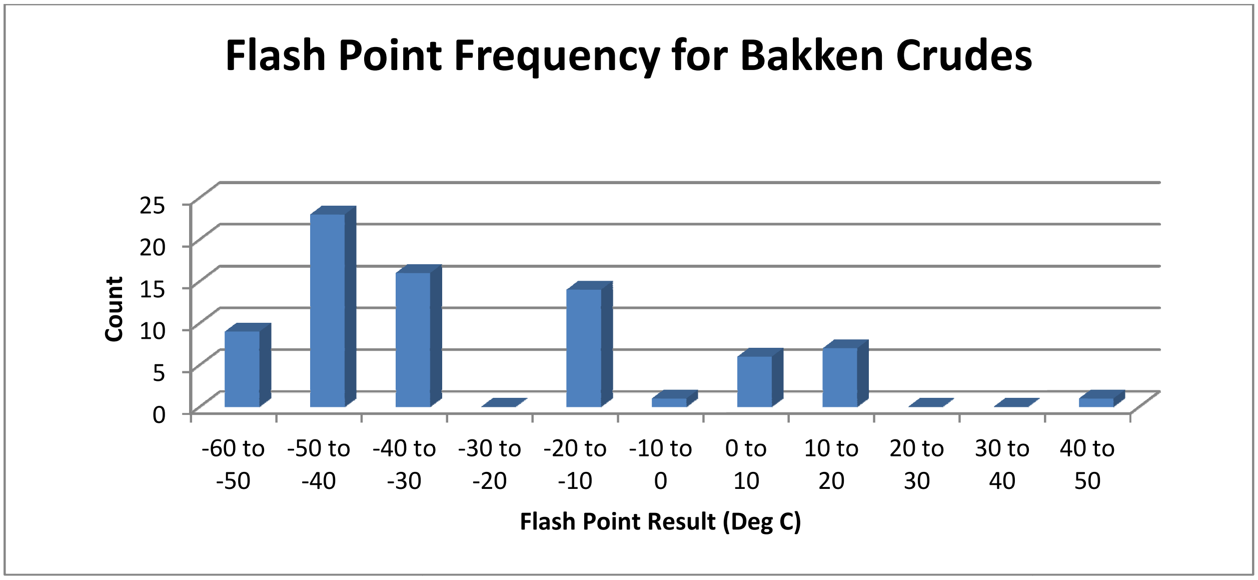
For comparison purposes data from samples of non-Bakken crude oil was also considered.

1. <u>Flashpoint</u>

Reported Bakken flashpoint range. Survey respondents reported flashpoints ranging from -59°C (-74°F) to 110°C (230°F). On the basis of this flashpoint information, Bakken crude oil in transportation ranges from being subject to regulation as flammable liquids (in all 3 Packing Groups), combustible liquids or not regulated as hazardous materials under the HMR.

The chart below shows the distribution of flashpoints among all Bakken crudes for which data was provided as part of this survey.

[19] Many of the samples were collected in February/March 2014 in North Dakota. Given the prevailing ambient temperature, these samples are expected to represent "worst case" conditions that contribute to higher flashpoint, vapor pressure and dissolved gasses.
[20] Data provided was initially acquired for a range of purposes and not necessarily for compliance with the HMR. As such data on samples did not always include data points on all of the characteristics considered in the survey.



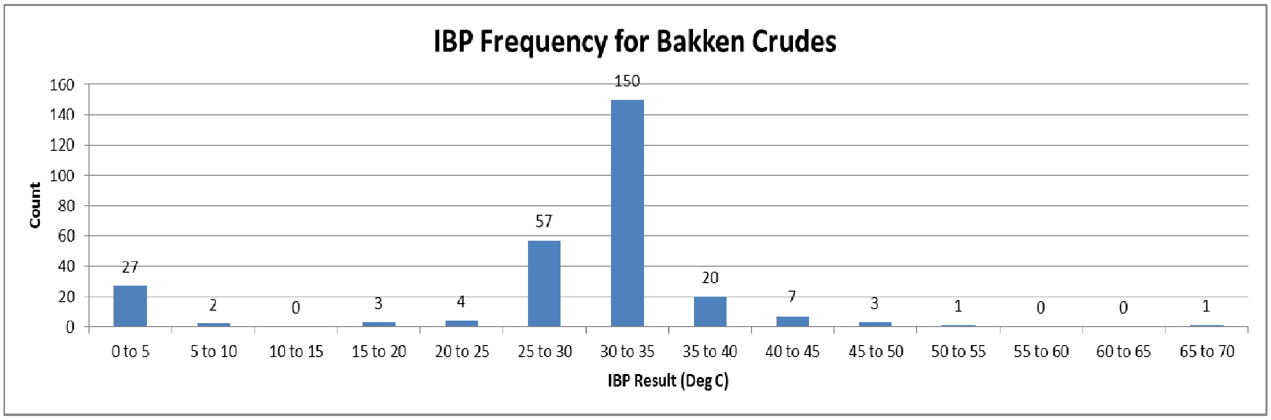
Mean	-27.1°C (-16.8°F)
Median	-36° C (-32.8°F)
Mode	-15.0 °C (5 °F)
Minimum	-59°C (-74.2°F)
Maximum	50°C (122°F)

Discussion on flashpoint data. Survey data indicate that 76 of the 77 crude oil samples meet the classification criteria for Packing Group I or II. One crude oil sample for which data was provided could be classified either as Packing Group III or as a combustible liquid.

As already noted, flashpoint data may be based on estimation methods with the objective of determining the HMR flashpoint range a particular crude oil falls into (e.g., 23°C or less). While these methods suffice for HMR classification purposes in that they assign a substance to the appropriate flashpoint range they may not accurately reflect the precise flashpoint value that would be obtained using a method identified as suitable under the HMR. As such caution is advised when considering specific values.

2. **Initial boiling point**

Reported Initial Boiling Points. The chart below describes the range of initial boiling point data that was provided on Bakken samples from crude oil in transportation.



Mean	29.0°C (69.6°F)
Median	30.7° C (87.3°F)
Mode	30.2 °C (86.4 °F)
Minimum	2.2°C (36.0°F)
Maximum	66.9°C (152.4°F)

Discussion on Initial Boiling Point information. Based on the data provided in the survey, the majority of Bakken crude oils in transportation have an initial boiling point ranging from 15°C to 50°C. The low values shown in the lower left hand side of the chart stem from samples taken upon arrival at a refinery in the months of February to April suggesting that IBP is influenced by seasonal conditions.

The HMR utilize an IBP threshold criterion of 35°C to delineate between Packing Group I and II. Among Bakken crude oils, IBP values are clustered around the regulatory threshold. Respondents to the survey noted problems with the variability and repeatability of IBP tests. While no misclassification is implied, the clustering of IBP values around the 35°C threshold value combined with repeatability problems associated with IBP testing could present practical challenges with respect to the assignment to Packing Group I or II.

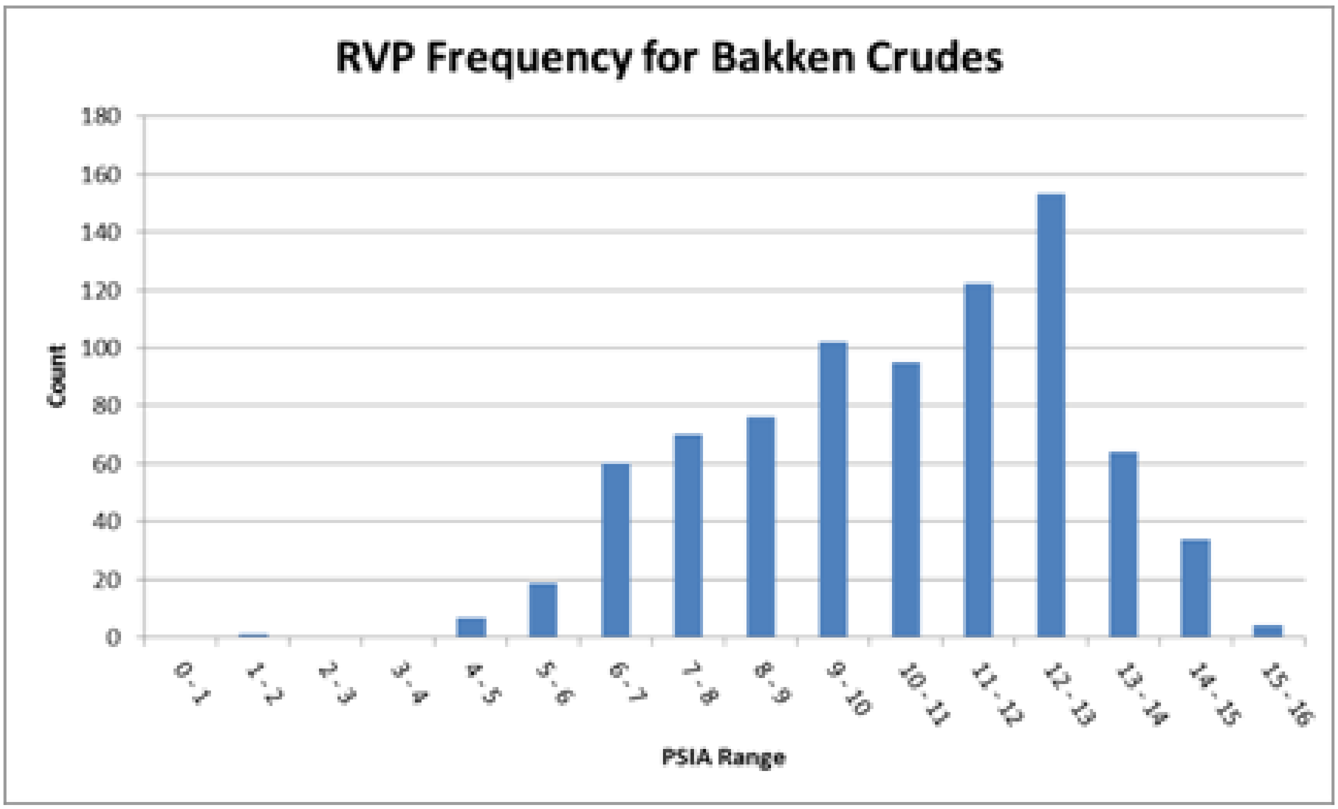
3. **Vapor pressure of crude oil in transportation, tank car pressures**

Reported vapor pressure at 50°C. Vapor pressure values were reported in data on nine Bakken samples. The vapor pressure values ranged from a low of 13.89 psia to 16.72 psia. Based on RVP data these values appear to be in the high range of what would normally be expected for Bakken crude oil – although well below the vapor pressure threshold for a flammable gas. All but two samples were taken at the rail loading point in North Dakota. These values were from samples taken in February and March 2014. Lower vapor pressure values would be anticipated at other times during the year when ambient temperatures are higher.[21] The data confirm that Bakken crude oils fall within the definition of a liquid under the HMR in that they are well below the 300 kPa (43 psia) threshold value delineating between a gas and a liquid.

Note that the vapor pressure at 50 ^{o}C will normally correlate closely with the far more widely reported RVP which is measured at 38 ^{o}C (100 ^{o}F) as discussed below.

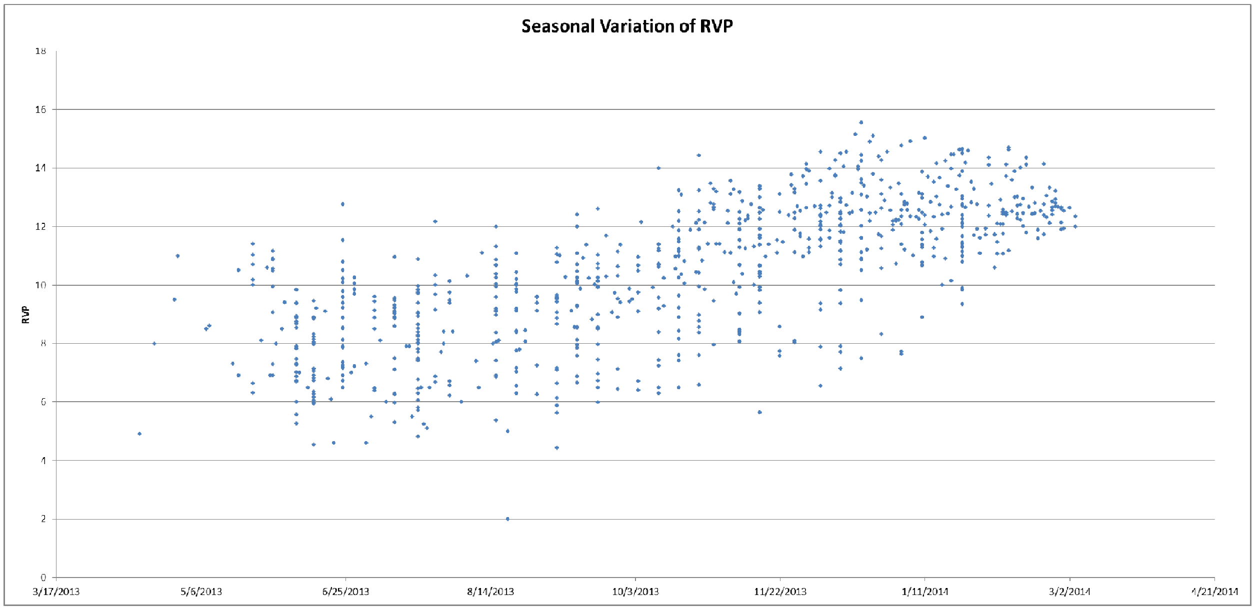
Reported Reid Vapor Pressure values (vapor pressure at 38 ^{o}C (100 ^{o}F)). Among the survey respondents and based on the data submitted, Bakken crude oil offered for transportation was found to have RVP values ranging from 0.8 to 15.54 psia.

The chart below shows the distribution of RVPs among all Bakken crudes for which data was obtained as part of this survey.



[21] The seasonal variation of RVP is discussed below.

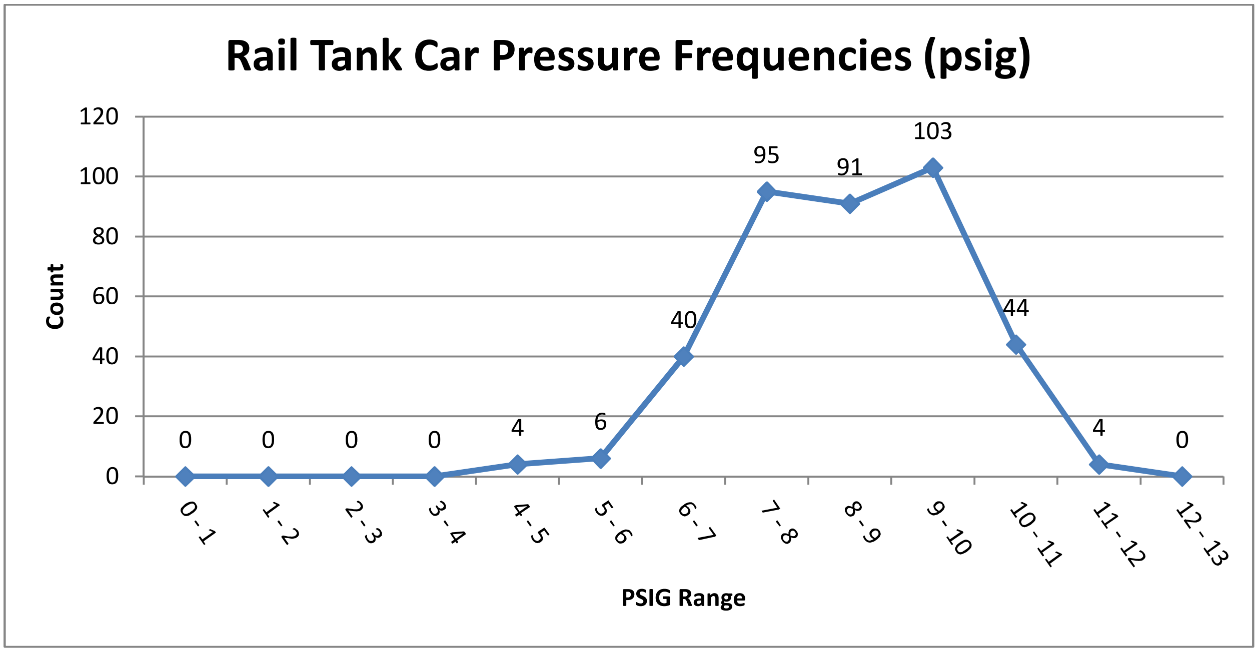
Seasonal variations of RVP. Seasonal variations of RVP are demonstrated in the following chart.



The chart shows that RVP values average 8 psia for warmer times of the year and average 12.5 psia during colder periods. RVP and other parameters are interrelated. As such, similar seasonal variations in other parameters such as flashpoint, initial boiling point, and flammable gas content are likely.

Operational limits on crude oil RVP. Respondents noted that, outside of the HMR, there are operational limits on the RVP of crude oil. First of all, it is common to store crude oil in floating roof tanks. Environmental regulations governing the release of volatile organic compounds (VOCs) restrict the RVP (or a variant known as TVP measured at ambient temperature) of crude oil in floating roof tanks to 10-11 psia. The floating roof tank pressure limits impose practical RVP limits on the crude oil transported by rail to refiners and petrochemical facilities. Recipients monitor crude oil for RVP to ensure compliance with these environmental regulations. One respondent noted that they test the RVP of every rail shipment at the time of loading and upon receipt. In their experience RVP values varied according to the time of year with RVP values as high as 15 psia in the winter and with lower RVP values typical in the summer. The second operational restriction on the transportation of high RVP value crude oils is due to increased potential for pump cavitation. A limiting RVP of 10 psia was reported as typical for crude oils transported by pipeline where pumping is required. Pipelines are a destination for some Bakken crude oils transported by rail. Finally, lower RVPs are also more desirable from a refinery operational perspective. One refinery respondent noted a contractual RVP limit of 9.5 psia.

Reported rail tank car pressure measurements. The chart below indicates pressures measured in rail tank cars upon arrival at a refinery. The highest value reported was 11.3 psig. This value is lower than the 35 psig minimum relief valve setting for older DOT 111 rail tanks cars and their required 240 psig minimum design burst pressure. This suggests that DOT 111's are built with an ample margin of safety relative to the pressures that rail tanks may experience when transporting Bakken crude oil.



Mean	8.5 psig
Median	8.5 psig
Mode	9.0 psig
Minimum	4.2 psig
Maximum	11.3 psig

4. Flammable Gas Content

Reported flammable gas concentrations. In response to the PHMSA question on ranges of flammable gas content of Bakken crude oil, respondents reported the following ranges:[22]

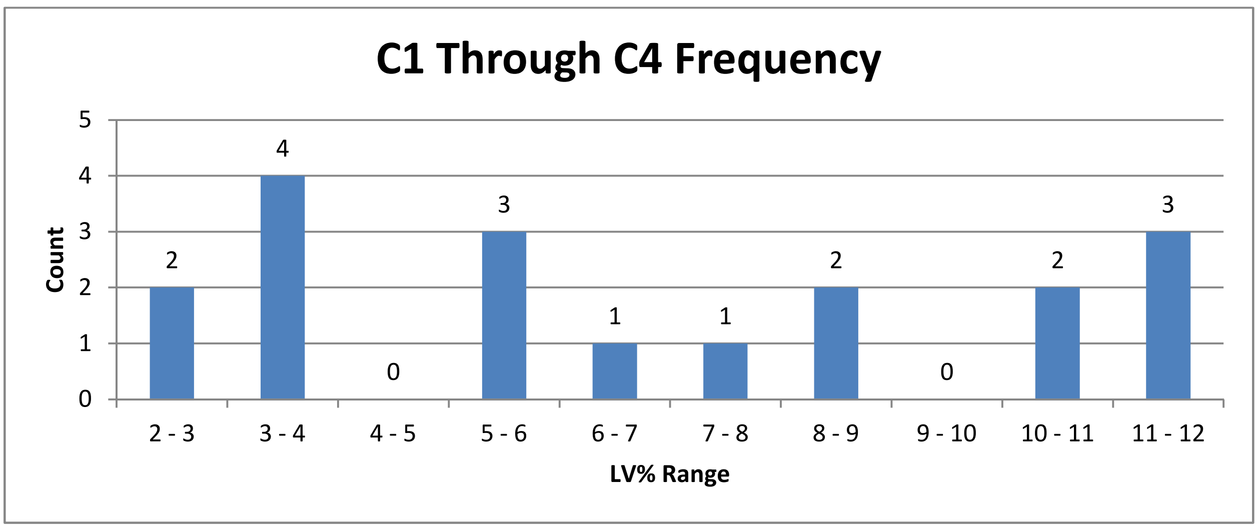
Hydrocarbon gas	Concentration in Liquid Volume %

[22] In data collected, some samples were found to have higher values than indicated in the range of values reported. Maximum values were 0.77 LV % for ethane, 3.4 LV % for propane, and 8.0 LV % for butane. As reflected in the bar chart below, based on sample data, the maximum total flammable gas content for all samples was 11.9 LV %. Samples were obtained in February and March.

Methane	<0.01
Ethane	0.50
Propane	<1-2%
Iso-, N-Butane	3-4%

Eighteen samples included measurements of flammable gas content. The information differs from light end content in that pentane, which is not a gas under the HMR, is commonly included in light end data. Data from three respondents indicated a maximum total flammable gas content (C1 to C4) of 3.5% Liquid Volume %.

Information provided by a fourth respondent, included data from 12 samples taken in a one month period beginning in early February and ending in early March. In the case of the latter samples, total flammable gas content ranged from 5.9% to 11.9%. Ambient temperatures affect these gas concentration values. The data obtained from all respondents is illustrated in the chart below.



Comparison with other crude oils. To determine whether Bakken crude oil's "light end" content is markedly different from other crude oils, data (primarily from assays) for other non-Bakken crude oils were examined.[23] The table below illustrates that some selected other crude oils have comparable gas contents and in addition illustrates some of the variations in characteristics that exist among crude oils with a range of API gravities. (Note that "light ends" as the term is used in the petroleum industry includes pentanes which are deemed flammable liquids under the HMR.) Based on assay data for Bakken and non-Bakken crude oils[24], the following table summarizes data obtained:

Crude Name	**Origin**	**API**	**RVP (psia)**	**Vol % of Light Ends (C2 – C5)**
Arabian Super Light	Saudi Arabia	51	20.7	12.53 wt %[25] (C1-C4 only)
Eagle Ford	Texas	48	7.95	8.3
Agbami	Nigeria	48	2.2	5.61 wt %
DJ Basin	Colorado	45	7.82	8.0
Sarahan Blend	Algeria	43	7.46	8.1
Bakken	North Dakota	42	7.83	7.2
WTI	Texas / New Mexico	41	5.90	6.1
Brent[26]	United Kingdom	37.5	9.33	5.28 wt %
API gravity of 37 or more defines light crude oil		37		
LLS	Louisiana	36	4.18	3.0
Alvheim blend	Norway	34.9	3.9	1.86 wt %
Arabian Heavy	Saudi Arabia	28.4	18.3	5.13 wt % (C1-C4)
Alberta Dilbit[27]	Alberta	21.1	7.18	7.30 wt %
Alba	United Kingdom	19.6	1.6	0.14 wt %

[23] *Note* "light ends" as the term is used in the petroleum industry includes pentanes which are deemed flammable liquids under the HMR.
[24] Sources included data collected as part of the survey as well as online data at http://www.oil-transport.info/crudedata/crudeoildata/crudeoildata.html and data at http://www.statoil.com/en/ouroperations/tradingproducts/crudeoil/crudeoilassays/pages/default.aspx
[25] Because the specific gravities of gases and pentanes in the liquid state are lower than that of other components, "wt %" is lower than "LV %". Conversion from wt % to LV% requires the concentrations of each individual component.
[26] Data from a sample taken at the loading point.
[27] Data from a sample taken at the loading point.

Using assay data allows for evaluating oils on a consistent basis. While survey data on specific samples of Bakken crude oils (like other light crude oils) showed higher gas content than assay data, it may be expected that similar variations arise in the case of non-Bakken crude oils. The data suggests that Bakken crude oil is within the norm for what might be expected in the case of light end content in light crude oils. Light crudes oils are not unique to new drilling practices and have been common since the advent of petroleum extraction.

Operational limits on flammable gas content. Since flammable gas content and vapor pressure are closely linked, operational limitations identified relative to RVP (i.e., floating roof tank limits, pipeline pumping limits and refinery operational considerations) also apply in the case of flammable gas concentrations.

5. Hydrogen sulfide content

Reported hydrogen sulfide concentrations. Respondents indicated hydrogen sulfide vapor space concentrations were less than 10 ppm.

Data reviewed was for either hydrogen sulfide concentration in the liquid or hydrogen sulfide concentration in the vapor.

Data on H_2S in liquid. For samples, hydrogen sulfide concentrations (in ppm) in the liquid were reported as follows:

H2S in liquid	Count
x< 0.2	4
x<1.0	2
x< 2	22
x<5.0	1
x< 10	8
Total	**37**

These would suggest very low hydrogen sulfide vapor concentrations.

Data on H_2S in vapors. Reports of hydrogen sulfide (in ppm) in the vapor were reported as follows:

H2S in Vapor	Count
x<1	390
x<2.0	9
x>2000	6
Total	**535**

The above six values indicating “x>2000” stemmed from one of four respondents providing H_2S vapor data. In addition, the same respondent reported 129 measured H_2S values (in ppm) that are summarized as follows:

H2S in Vapor	
Mean	3580
Median	2000
Min	1
Max	23000

The data was based on samples taken at a gathering location where crude oil was being collected for transportation. For crude oils with H_2S concentrations posing an inhalation hazard, additional HMR hazard communication requirements apply, including warnings on rail tanks cars.[28]

Operational limits on hydrogen sulfide. With an OSHA short term exposure limit (STEL) of 15 ppm for 15 minutes exposure, occupational limits are far below those warranting communication of the toxic hazard under the HMR. Where there is potential for exposure, employees are fitted with monitors and ambient air is subject to gas sampling. Testing for hydrogen sulfide is common for rail unloading operations and one respondent noted that hydrogen sulfide levels greater than 15 ppm were not allowed at company rail unloading facilities. Another respondent noted that where high hydrogen sulfide crude oils are encountered, the crude oil is typically not transported before first being subjected to treatment using amine scavengers.

When appropriate, based on potential high levels of hydrogen sulfide which pose a health risk to workers, the risks of hydrogen sulfide are delineated on Safety Data Sheets.

6. Corrosivity to metals

Discussion. Under the HMR, in addition to criteria for corrosivity to skin, a substance is regarded as corrosive if it corrodes steel or aluminum at a rate of 6.25 mm (0.25 inches) per year. A substance with this degree of corrosivity would penetrate steel used in crude oil rail tank cars in a period of approximately two years. There is no evidence that Bakken crude corrodes steel or aluminum at this rate.

Reported corrosivity data. Data reported using NACE TM 172 indicates that Bakken crude oil scores as either B+ or B++ using this method. Generally, a NACE value of B+ or better is

[28] *See* 49 CFR §172.327.

required for transportation via pipeline. While crude oil does not meet the HMR corrosivity criteria, water, solids and H2S contaminants in crude may cause corrosion at rates less than that specified in the HMR for classification purposes. Industry deals with this lower level of corrosion from an asset management perspective.

D. What safety information is provided to carriers?

The HMR require that a considerable amount of information be provided to carriers, including:

1. UN number of the crude oil;
2. Proper shipping name under which it is transported;
3. Hazard class (Class 3);
4. Packing Group of the crude oil;
5. Total quantity being offered or the number of packagings (i.e., rail tank cars) involved;
6. Emergency response information that includes immediate hazards to health; risks of fire or explosion; intermediate methods to be taken for handling fires; initial methods for handling spills or leaks in the absence of a fire; and preliminary first aid measures; and
7. A 24-hour emergency telephone number where more detailed information may be obtained.

Upon request, carriers may also be provided material safety data sheets.

IV. Summary Remarks

Survey results obtained by AFPM members provide a considerable amount of information on which to assess the hazard characteristics of Bakken crude oil. The data obtained appears to be of good quality. From the data, it is clear that parameters such as vapor pressures, initial boiling points, flashpoints and dissolved gas content were influenced by seasonal variations. Yet even when considering data obtained during periods of cold weather, Bakken crude oil was found to be well within the limits for what is acceptable for transportation as a flammable liquid. Bakken crude oil was compared with other light crude oils and determined to be within the norm in the case of light hydrocarbon content, including dissolved flammable gases.

Measured tank car pressures show that even the older DOT 111's authorized to transport Bakken crude oil are built with a wide margin of safety relative to the pressures that rail tanks may experience when transporting Bakken crude oil.

Other factors influence the properties of crude that is transported. As manufacturers, AFPM members have an interest in limiting the RVP for purposes of operational efficiency and adherence to Clean Air Act requirements. RVP values correlate with values for flammable gas content, initial boiling point and flashpoint. Levels of all these parameters, consistent with an RVP of approximately 10 psia or lower are in the best interests of AFPM members. Compliance with OSHA requirements related to exposure to H_2S also plays a role in reducing the hydrogen sulfide content of crude oil in transportation.

AFPM and its members appreciate the concerns raised in relation to rail transport of Bakken crude oil and stand ready to work cooperatively with DOT and other governmental organizations to ensure the safe transportation of Bakken crude oil. This survey shows that Bakken crude oil does not pose risks that are significantly different than other crude oils and other flammable liquids authorized for transportation as flammable liquids. In some respects Bakken crude oil may be regarded as posing a lower degree of risk than other flammable liquids transported in accordance with the HMR, particularly pure substances.[29]

[29] Some examples of other Class 3 Flammable Liquids that are transported in DOT 111's with a higher risk profile than Bakken crude would include: diethyl ether, acrylonitrile, and ethyl mercaptan.

Appendix 1

U.S. Department
of Transportation
**Pipeline and Hazardous
Materials Safety
Administration**

Administrator

1200 New Jersey Ave., S.E.
Washington, DC 20590

January 29, 2014

Mr. Charles Drevna
American Fuel and Petrochemical Manufacturers
1667 K Street, NW
Suite 700
Washington, DC 20006

Dear Mr. Drevna:

The recent railroad derailments and resulting fires in North Dakota, Alabama, New Brunswick, Ontario, and Lac-Megantic, Quebec have raised my concerns about the safety risks associated with the transportation of crude oil, specifically the crude oil originating from the Bakken region. One concern is whether this product has inherent properties and characteristics different from traditional crude oils historically transported and whether these characteristics pose additional transportation risks. In order to address my concerns, I invite you to meet with me in Washington, DC on Wednesday, February 5, 2014, from 10 a.m. to 11:30 a.m. at Department of Transportation headquarters to discuss potential safety issues related to truck and rail transportation of crude oil. I am specifically concerned about the methods and processes you use to meet your responsibilities in the Hazardous Material Regulations to properly test, characterize, and classify the crude oil for transportation by truck and rail.

Based upon preliminary information obtained from investigations into the derailments noted above, PHMSA issued a safety alert to the industry reiterating the requirement to properly test, characterize, and classify hazardous materials prior to transportation. Title 49 Code of Federal Regulations §172.204 requires offerors of hazardous materials to properly classify and describe the hazardous materials being offered for transportation. As part of this process, offerors must ensure that all potential hazards are properly characterized and communicated on shipping papers. Proper characterization identifies those properties that could affect the integrity of the packaging or present additional hazards, such as corrosivity, sulfur content, and dissolved gas content, in addition to how the product is classified for transportation. Proper classification, packing group assignment, and communication of all the hazards of product shipments are required and fundamental to the safe transportation of these materials, regardless of the mode of transportation.

In order to have meaningful discussions during your visit, please consider and be prepared to answer the following questions:

- What tests or methods do you use to determine the properties of the crude oil to include its vapor pressure, flammable gas content, flash point, boiling point, hydrogen sulfide content and corrosive properties prior to offering it in transportation?
- Who performs these tests and how frequently are they completed?
- When you find high levels of gases in crude, what actions do you require of your oilfield personnel before loading into a transport vehicle? What information about the crude oil properties, if any, is provided by the producers to you prior to transportation? How is this information communicated?
- What information do you share with truck and rail carriers about the crude oil properties?
- Are there any prescribed limits involving vapor pressure, flammable gas concentration or hydrogen sulfide content above which the crude oil is not placed into transportation? If so, what are these limits and how are they determined?

I welcome your insights to these questions and any other information that you may have about the chemical and hazardous properties of Bakken crude oil. I look forward to meeting you and working together on this critical transportation safety issue.

We are also extending this invitation to anyone else that you believe would benefit from attending or further contribute to this meeting. My executive assistant, Sabrina Morris, will contact your office to schedule the meeting. If you have any questions, please feel free to call me at (202) 366-4433.

Regards,

Cynthia Quarterman

Cynthia L. Quarterman

Appendix 2

PHMSA Field Office Questionnaire

Company: ____________________________ **Contact Name:** ________________________

Address: ______________________________ **Title:** ________________________________

City, State: ___________________________ **Phone:** _______________________________

Type: Refinery ☐ Transfer Terminal ☐ **Email:** _______________________________

- What tests, if any, are performed on the crude oil upon receipt?
  - How frequently are they completed?
  - Are you willing to share the results with us?
- When you find high levels of gases in crude, what actions do you require of your personnel before unloading?
  - What information about the crude oil properties, if any, is provided by the offerors or carriers prior to receipt?
  - How is this information communicated?
- Have you had to add any special safety measures or make any procedural changes in the unloading process to protect workers or modify the flow to the facility?
- Are there any prescribed limits involving vapor pressure, flammable gas concentration or hydrogen sulfide content above which the crude oil is not accepted at terminal or refinery?
  - If so, what are these limits and how are they determined? (*Note: We have heard that one of the larger refineries in Canada placed gauges on top of rail cars to measure pressure before unloading and in turn rejected some 400 rail cars.*)

Appendix 3

United Nations

ST/SG/AC.10/C.3/2014/49

Secretariat

Distr.: General

2 April 2014

Original: English

Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labeling of Chemicals

Sub-Committee of Experts on the Transport of Dangerous Goods

Forty-fifth session

Geneva, 23 June – 2 July 2014

Item 4 (c) of the provisional agenda
Listing, classification and packing: miscellaneous

Classification and hazard communication provisions for crude oil

Transmitted by the experts from Canada and the United States of America[30]

Background

1. North America is experiencing a significant increase in crude oil supply, bolstered both by growing production in the Canadian oil sands and the recent expansion of shale oil and natural gas production in the United States of America and Canada.

2. North American shale oil and natural gas extraction has been mostly in geographic areas not linked to traditional crude oil or natural gas pipelines, resulting in an increase in surface transport. Surface transport has also enabled crude transport to different refinery capacities situated across North America. This mostly "younger" crude is being found to contain significantly higher "light ends" than what has been traditionally transported as UN 1267.

[30] In accordance with the programme of work of the Sub-Committee for 2013-2014 approved by the Committee at its sixth session (refer to ST/SG/AC.10/C.3/84, para. 86 and ST/SG/AC.10/40, para. 14).

3. This significant and exponential increased in surface movement of crude oil has led authorities within Canada and the United States of America to carefully consider transport safety impacts as well as potential impacts to the environment. These efforts have been prioritized based on a series of major accidents across North America involving crude oil transport by rail - including a catastrophic incident brought to the attention of the Sub-Committee at its previous session that caused numerous fatalities and destroyed much of Lac Mégantic, Quebec, in July 2013.

4. The increased production and experience has led to a renewed focus within North America on assessing the adequacy of the current provisions governing crude oil transport. While an assessment of relevant rail operational conditions have been major components of this effort, a significant portion of the experience gained is relevant to all modes and would benefit from broader review and discussion within the Sub-Committee. The purpose of this paper is to initiate discussions relevant to the experience recently gained, to raise important questions regarding the proper classification of - and transport provisions for – crude oil, and to invite the Sub-Committee to consider whether a review of the existing UN entries, assigned classifications, and transport provisions is warranted. This discussion may also eventually encumber other petroleum products such as natural gas condensates.

5. In particular, the Sub-Committee is invited to consider whether the current entries for crude oil in the Dangerous Goods List adequately distinguish between what can be significant variations in the flammable gas content of crude oils from different sources (see discussion below relevant to classification).

Discussion

6. This document contains no proposals. The Sub-Committee is invited to provide feedback as a first step towards evaluating the efficacy of the current provisions of the Model Regulations based on an evolving understanding of the risks inherent in the transport of crude oil. Specifically, based on the information available on various types of crude oils in global transport today, the Sub-Committee is requested to provide feedback with respect to the classification and hazard communication elements of the Model Regulations currently applicable to crude oil.

(a) Classification

Unlike other Class 3 manufactured goods, organic materials from oil and gas production represent a unique challenge in regards to classification. Differences in the chemical makeup of the raw material can vary day-to-day and from well head-to-well head. Unprocessed crude oil may present unique hazards based on the specific dissolved gas content, posing different hazards in transport. Would further distinctions beyond merely identifying the Packing Group relevant to the flammable liquid hazard or the flammable gas content of the crude be appropriate to account for the differing hazards posed by what can be significant quantities of dissolved flammable gases? What is the most appropriate measure of this volatility – boiling point or vapour pressure? Is the proposed measurement method a calculation based on the properties of the material or an observed value? What are the most appropriate sampling and testing procedures? And finally, at what threshold should revisions to the regulatory requirements be considered?

(b) Hazard communication

The current flammable liquid entries in the Dangerous Goods List provide for a distinction in hazard by the assignment of Packing Groups based on the liquid's boiling and flash points. However, lighter crude oil with a higher quantity of dissolved flammable gases pose a significantly different risk than heavier crude oils that do not have such a high constituency of more volatile components. Would enhanced hazard communication distinguishing more volatile crude oils be beneficial for transport workers and emergency response personnel? If so, would a new table entry for such a material be sufficient?

Conclusion

7. The Sub-Committee is invited to consider appropriate next steps to ensure that the provisions of the Model Regulations adequately address the risks posed by the transport of crude oil. Based on the feedback received at this session, the experts from Canada and the United States of America would be willing to prepare specific proposals for consideration at a future session.

Appendix 4

Test methods used to evaluate selected Bakken Crude Oil Characteristics

1. Flashpoint *(Note: Some reported using the methods referenced in §173.120(c).)*
   - ASTM D56 Standard Test Method for Flash Point by Tag Closed Cup Tester
   - ASTM D93 Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester
   - ASTM D3278 Standard Test Methods for Flash Point of Liquids by Small Scale Closed-Cup Apparatus

2. Initial boiling point *(Note: Some reported using the methods referenced in §173.121(a)(2).)*
   - ASTM D86 Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure
   - ASTM D1160 Standard Test Method for Distillation of Petroleum Products at Reduced Pressure
   - ASTM D2887 Standard Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography
   - ASTM D5134 Standard Test Method for Detailed Analysis of Petroleum Naphthas through n-Nonane by Capillary Gas Chromatography
   - ASTM D7169 Standard Test Method for Boiling Point Distribution of Samples with Residues Such as Crude Oils and Atmospheric and Vacuum Residues by High Temperature Gas Chromatography

3. Vapor pressure
   - ASTM D2879 Standard Test Method for Vapor Pressure-Temperature Relationship and Initial Decomposition Temperature of Liquids by Isoteniscope
   - ASTM D5191 Standard Test Method for Vapor Pressure of Petroleum Products (Mini Method)

4. Flammable gas content
   - ASTM D-5134 Standard Test Method for Detailed Analysis of Petroleum Naphthas through n-Nonane by Capillary Gas Chromatography
   - ITM 6008 Light ends analysis by Gas Chromatography
   - IP 344 Determination of light hydrocarbons in stabilized crude oils - Gas chromatography method

5. Hydrogen sulfide content
   - ASTM D5705 Standard Test Method for Measurement of Hydrogen Sulfide in the Vapor Phase Above Residual Fuel Oils

- IP 507: Determination of boiling range distribution by gas chromatography method - Part 2: Heavy distillates and residual fuels
- UOP163 Hydrogen Sulfide and Mercaptan Sulfur in Liquid Hydrocarbons by Potentiometric Titration

6. Corrosivity to metal
   - NACE TM172 Standard Test Method - Determining Corrosive Properties of Cargoes in Petroleum Product Pipelines

Appendix 5

Guide 128 from the 2012 ERG

GUIDE 128 Flammable Liquids (Non-Polar/Water-Immiscible)

FIRE OR EXPLOSION

• HIGHLY FLAMMABLE: Will be easily ignited by heat, sparks or flames.
• Vapors may form explosive mixtures with air.
• Vapors may travel to source of ignition and flash back.
• Most vapors are heavier than air. They will spread along ground and collect in low or confined areas (sewers, basements, tanks).
• Vapor explosion hazard indoors, outdoors or in sewers.
• Those substances designated with a **(P)** may polymerize explosively when heated or involved in a fire.
• Runoff to sewer may create fire or explosion hazard.
• Containers may explode when heated.
• Many liquids are lighter than water.
• Substance may be transported hot.
• For UN3166, if Lithium ion batteries are involved, also consult GUIDE 147.
• If molten aluminum is involved, refer to GUIDE 169.

HEALTH

• Inhalation or contact with material may irritate or burn skin and eyes.
• Fire may produce irritating, corrosive and/or toxic gases.
• Vapors may cause dizziness or suffocation.
• Runoff from fire control or dilution water may cause pollution.

• CALL EMERGENCY RESPONSE Telephone Number on Shipping Paper first. If Shipping Paper not available or no answer, refer to appropriate telephone number listed on the inside back cover.
• As an immediate precautionary measure, isolate spill or leak area for at least 50 meters (150 feet) in all directions.
• Keep unauthorized personnel away.
• Stay upwind.
• Keep out of low areas.
• Ventilate closed spaces before entering.

PROTECTIVE CLOTHING

• Wear positive pressure self-contained breathing apparatus (SCBA).
• Structural firefighters' protective clothing will only provide limited protection.

EVACUATION

Large Spill
• Consider initial downwind evacuation for at least 300 meters (1000 feet).
Fire
• If tank, rail car or tank truck is involved in a fire, ISOLATE for 800 meters (1/2 mile) in all directions; also, consider initial evacuation for 800 meters (1/2 mile) in all directions.

FIRE

CAUTION: All these products have a very low flash point: Use of water spray when fighting fire may be inefficient.
CAUTION: For mixtures containing alcohol or polar solvent, alcohol-resistant foam may be more effective.
Small Fire
• Dry chemical, CO_2, water spray or regular foam.
Large Fire
• Water spray, fog or regular foam.
• Do not use straight streams.
• Move containers from fire area if you can do it without risk.
Fire involving Tanks or Car/Trailer Loads
• Fight fire from maximum distance or use unmanned hose holders or monitor nozzles.
• Cool containers with flooding quantities of water until well after fire is out.
• Withdraw immediately in case of rising sound from venting safety devices or discoloration of tank.
• ALWAYS stay away from tanks engulfed in fire.
• For massive fire, use unmanned hose holders or monitor nozzles; if this is impossible, withdraw from

area and let fire burn.

SPILL OR LEAK

• ELIMINATE all ignition sources (no smoking, flares, sparks or flames in immediate area).
• All equipment used when handling the product must be grounded.
• Do not touch or walk through spilled material.
• Stop leak if you can do it without risk.
• Prevent entry into waterways, sewers, basements or confined areas.
• A vapor suppressing foam may be used to reduce vapors.
• Absorb or cover with dry earth, sand or other non-combustible material and transfer to containers.
• Use clean non-sparking tools to collect absorbed material.

Large Spill

• Dike far ahead of liquid spill for later disposal.
• Water spray may reduce vapor; but may not prevent ignition in closed spaces.

FIRST AID

• Move victim to fresh air.
• Call 911 or emergency medical service.
• Give artificial respiration if victim is not breathing.
• Administer oxygen if breathing is difficult.
• Remove and isolate contaminated clothing and shoes.
• In case of contact with substance, immediately flush skin or eyes with running water for at least 20 minutes.
• Wash skin with soap and water.
• In case of burns, immediately cool affected skin for as long as possible with cold water. Do not remove clothing if adhering to skin.
• Keep victim warm and quiet.
• Ensure that medical personnel are aware of the material(s) involved and take precautions to protect themselves

Appendix 6

Glossary of Terms and Acronyms

AFPM means the American Fuel & Petrochemical Manufacturers.

DOT means U.S. Department of Transportation.

ERG means the Emergency Response Guidebook produced by PHMSA in cooperation with the governments of Canada and Mexico and used throughout North America as the basis for the initial response to a hazardous materials emergency.

Flashpoint means the lowest temperature at which a liquid or gas produces a concentration of vapor in air that may be ignited.

H_2S means hydrogen sulfide.

HMR the Hazardous Materials Regulations in 49 CFR Parts 105 to 180.

IBP means initial boiling point.

OSHA means the Occupational Safety and Health Administration.

PHMSA means the DOT Pipeline and Hazardous Materials Administration.

Packing Group means the degree of hazard assigned to materials subject to the DOT HMR according to specified criteria. Hazard levels of Packing Group I (high), II (medium) and III (low) are possible.

RVP means Reid Vapor Pressure.

STEL means short term exposure limit for a specific substance in air. The value is commonly based on 15 minutes exposure.

TVP means True Vapor Pressure.