

Crude Quality Inc. Report regarding the U.S. Department of State Supplementary Draft Environmental Impact Statement

Executive Summary

The following has been prepared by Crude Quality Inc. (CQI) in response to the U.S. Department of State Supplementary Draft Environment Impact Statement (SDEIS) for the Keystone XL Pipeline. Crude Quality Inc. was retained to review and provide an independent expert assessment of the crude quality aspects included in the U.S. Department of State SDEIS. This report will include supplementary information related to dilbit homogeneity, crude volatility and crude petroleum acidity. In addition, Crude Quality Inc. will provide suggestions related to the data presented in the U.S. Department of State Supplementary Draft Environment Impact Statement.

The report that follows is based primarily on the intrinsic qualities and behaviours of dilbit crudes. As a fully homogeneous mixture, a dilbit will not spontaneously separate into its base components. In the absence of separation, it is impossible to state that the risks associated with the individual components will have any effect on the transportation of the blended product. Furthermore, any risks that are associated with a dilbit are equally applicable to conventional crude products and are equally manageable through routine transportation safety methods. For these reasons, Crude Quality Inc. supports the information and conclusions presented by the U.S. Department of State in their Supplemental Draft Environmental Impact Statement.

Crude Quality Inc.

Crude Quality Inc. (CQI) is an Alberta-based incorporated business that has been serving western Canadian crude oil markets for over ten years. Based on extensive experience with matters related to the intrinsic quality of crude petroleum products, CQI has established a strong reputation both locally and beyond. One of CQI's most visible efforts related to crude quality can be found in the form of a publicly accessible website: crudemonitor.ca. This website was designed, developed, and maintained by Crude Quality Inc. and offers crude oil information in the form of basic crude properties, light ends characterization, and both simulated and physical distillation. Crude Quality Inc. has also performed a wide variety of crude petroleum quality related consulting projects for various clients.

In addition to CQI's direct and ongoing initiatives related to crude petroleum quality, CQI is involved with the Canadian Crude Quality Technical Association (CCQTA) and is represented on the board of directors of the US-based Crude Oil Quality Association (COQA). CQI has delivered presentations on general and specific crude petroleum quality topics at numerous conferences, including the National Petrochemical and Refiners Association (NPRA) and has appeared before arbitration hearings as an expert in the domain of crude petroleum quality.

Overview

A recent report targeted at the TransCanada Keystone Pipeline, LP application to the U.S. Department of State for a Presidential Permit has come to the attention of industry. The proponents of this report have made various claims related to the nature of crude oil quality and the risks associated with its transportation, especially with regards to Alberta's dilbit crude products. In a February 2011 news release, the Energy and Resource Conservation Board (ERCB) addressed the claims specifically related to pipeline failure rates and safety of the Alberta pipeline systems. In addition, the U.S. Department of State (DOS) issued a response in the form of a Supplemental Draft Environmental Impact Statement (SDEIS). Crude Quality Inc. (CQI), an Alberta-based company with extensive experience with Western Canadian Sedimentary Basin (WCSB) dilbit production, was retained to review and provide an independent expert assessment of the crude quality aspects included in the U.S. Department of State SDEIS.

Based on this arms-length review of the information presented in the SDEIS, particularly the materials included in section 3.13.5.1., Crude Quality Inc. is satisfied that statements made within the SDEIS document clearly and concisely address the misleading and materially incorrect statements put forth regarding the quality and properties of dilbit. Since the SDEIS document makes specific references to materials directly taken from websites operated and maintained by Crude Quality Inc.^{1,2}, we will provide suggestions and comments related to the data presented in the SDEIS.

¹ www.crudequality.ca

² www.crudemonitor.ca

Dilbit Homogeneity

“...[D]iluents are integrally combined into the crude oil and would not physically separate if the oil [was] accidentally released.” – U.S. Department of State Supplemental Draft EIS, Keystone XL, pg 3-104

Recent claims have been made with reference to the compositional nature of a diluted bitumen crude. These claims suggest that, unlike a “conventional” crude such as West Texas Intermediate (WTI), a dilbit could potentially separate into its individual components – diluents and raw bitumen. It should be noted, however, that even conventional crudes are considered blended mixtures of various crude materials. WTI, for example, consists of a number of component streams collected throughout West Texas. In this regard, a mixture of diluent and bitumen, which is commonly referred to as a “dilbit”, should be considered similar to WTI as both are fully homogenous mixtures and not merely loose collections of separate materials. To imply that dilbit blends will separate into individual components is simply unrepresentative of the realities of the situation. Furthermore, we would argue that considering the physical properties and risks of each individual component independently is both inconsistent with the known behaviour of the dilbit blend and unrepresentative of the realities of a blended crude product. To support this position, we will begin with a review of the makeup and typical behaviour of a dilbit.

A dilbit is a fully homogenous blend, and not a mixture that would spontaneously separate into its constituent components of diluent and bitumen. As is the case for all blended streams of crude oil, a dilbit should be considered a completely homogeneous mixture of hydrocarbon molecules. In 2006, an experiment was undertaken by Dr. Steve R. Larter at the University of Calgary to show that the physiochemical properties of a dilbit remain constant through the entirety of a simulated distillation

(SimDist). In this experiment, Larter's process involved the removal of the naphtha component, filtration, and a final recombination of the naphtha and bitumen phases.^[3] This experiment used dilbit samples from Suncor Energy in Athabasca, Alberta. One of the key goals of Larter's experiment was to show that the dilbit was a completely homogeneous mixture. To achieve this end, Larter's team performed a SimDist analysis, as well as multiple runs of a Karl-Fischer titration to determine the percentage of water. Very similar results were obtained for each fraction with a relative standard deviation of 1.4% or less through both methods. This would suggest that the sampling was successful and, furthermore, that the dilbit mixture was homogeneous. This experiment also demonstrates that to effectively remove the diluent component from dilbit, some form of microdistillation must be utilized. That is, diluent and bitumen components of dilbit simply will not separate without processing.

Implications of Dilbit Homogeneity

“While the raw bitumen produced from the WCSB oil sands is more dense than water, the specific gravity of the crude oils that would be transported on the proposed pipeline ranges from about 0.85 to about 0.93, less than the specific gravity of water. These [dilbit crudes], therefore, tend to float on water and would not initially sink if released to an aqueous environment, either at the surface or in the ground”. – U.S. Department of State Supplemental Draft EIS, Keystone XL, pg 3-104

The very process by which dilbit is created suggests that, under standard conditions, the diluent and bitumen will not separate and the diluted bitumen will float on water^[4]. When bitumen is extracted from the ground, it undergoes a process to remove the unwanted sand, clay and water. Under a

³ Integrated Sampling and Work-up Methodology for Providing Representative Bitumen Products for Characterization Studies, November 2006-2007, <http://www.ucalgary.ca/files/herringh/Integrated%20sampling%20and%20work-up%20methodology%20for%20providing%20representative%20bitumen%20products%20for%20characterization%20studies.pdf>

⁴ Patent Storm, on the conventional process for the production of dilbit, June 8 2004 <http://www.patentstorm.us/patents/6746599/description.html>

conventional crude production process, this involves adding a diluent to bitumen, thereby reducing the density of the bitumen and creating a density differential between the water and the dilbit. This new mixture then moves to a separation chamber where the heavier sand and solid particulates settle to the bottom, water settles in a middle portion, and the diluted bitumen, or dilbit, rises to a top layer where it can then be removed. The end result is a dilbit that, having been dehydrated to meet pipeline specifications, is ready for transport. Two general observations can be taken from this standard process. First, it is clear that the interaction between bitumen and diluents is such that the two components combine to form a single homogeneous mixture which remains cohesive even through a separation process. Second, the diluted bitumen, having undergone a density based separation from water as part of the production process, has effectively created a precedent for its behaviour in future contact with water.

Certain reports have, quite accurately, indicated that the density of raw bitumen is greater than of water; that is, it has been noted that bitumen is heavier than water. But, these reports fail to recognize that “[r]aw bitumen is solid under ambient conditions and therefore must be diluted or converted prior to transport via pipeline”^[5]. Western Canadian Select (WCS), one of the crude oils that could be transported by the Keystone XL project, has a typical density of roughly 930 kg/m³ with a standard deviation of 5^[6]. Based on this density, it is evident the WCS crude stream is NOT heavier than water. It is the density of the fully homogeneous overall product that allows a dilbit crude to be transported by pipeline, and not the densities of the individual components. As such, standard pipeline transportation practices and methods can be carried out as the dilbit will behave in accordance with its “whole crude” physical properties.

⁵ Supplemental Draft Environmental Impact Statement for Keystone XL, 3-104, http://www.keystonepipeline-xl.state.gov/clientsite/keystonexl.nsf/04_KXL_SDEIS.pdf?OpenFileResource

⁶ <http://crudemonitor.ca/crude.php?acr=WCS>

Product Volatility

“Crude oil releases are very unlikely to result in an explosion because crude oil contains a relatively small proportion of volatile hydrocarbons and most spills do not occur in confined spaces which allow the buildup of vapors to potentially explosive levels. Almost all “petroleum or hydrocarbon pipeline explosions” occur in pipelines that are transporting highly flammable, highly volatile hydrocarbons such as natural gas, LPG, propane, LNG, gasoline, naphtha, and similar products.” – U.S. Department of State Supplemental Draft EIS, Keystone XL, pg 3-133

Light crude oils with densities at or around 825 kg/m³, such as the WTI and various feeds that comprise the Mixed Sweet Blend (MSW), in fact contain more “diluent-type” molecules than heavier dilbits (~36 vol% for WTI versus ~20 vol% for benchmark dilbits). A crude is classified as light (or low density) based on the fact that it contains more small chain hydrocarbons that have a smaller molecular weight and density^[7]. These small chain hydrocarbons, which have lower flash temperatures than the longer chain molecules^[8], are the primary ingredients of diluent. Thus, the assumption that there is a higher likelihood of diluent combustion in a dilbit, versus a conventional crude, is simply inconsistent with the quantity makeup of the respective materials. In fact, conventional crudes, which contain a greater proportion of the volatile molecules, will certainly have a greater risk of combustion.

The physical and chemical characteristics of the base molecules that comprise diluent are identical, whether molecules are in conventional or bitumen-derived products. Thus, it is inconsistent to argue that the molecules from a dilbit blend are inherently more volatile than the same molecules in a conventional product. This is not to say that there is no risk of combustion associated with the handling and transportation of a dilbit crude. But, this risk, which is relative to that of any other crude oil product,

⁷ Oil and Gas Glossary, definition of heavy crude oil, <http://oilgasglossary.com/heavy-crude-oil.html>

⁸ The Properties of Petroleum Fluids, William D. McCain, Jr., 1989

can be properly mitigated through existing industry recognized regulations and responsible handling methods.

Sources have also suggested that the combustion of a dilbit could potentially release toxic by-products, such as hydrogen sulphide. In fact, sulphur combustion produces sulphur dioxide and, in practice, combustion techniques are commonly used to mitigate hydrogen sulphide emissions. Furthermore, hydrogen sulphide risk is not limited solely to dilbit products. The Material Safety Data Sheets (MSDS), which are used for all types of crude petroleum oil, list hydrogen sulphide as a potential inhalation hazard.^[9] Therefore, it is incorrect to claim that the health risks from hydrogen sulphide are unique to dilbit crudes.

Crude Petroleum Acidity

“...[T]he TAN characteristics of crude oils are not significant to the corrosion potential of steel piping at temperatures below approximately 450 degrees Fahrenheit (PHMSA 2011). The maximum operating temperature of the proposed Project pipeline would not exceed 150 degrees Fahrenheit.” – U.S. Department of State Supplemental Draft EIS, Keystone XL, pg 3-112

Certain organizations have argued that a dilbit is more corrosive than conventional crude because of the former's higher acid content. These statements are, however, quite misleading. The total acid number (TAN) of dilbit is a measure of the organic, or naphthenic, acid content associated with the crude. These acids are not the same as mineral acids with which the general public is more familiar. Concentrated mineral acids such as muriatic or sulphuric acids are highly aggressive towards steels at atmospheric pressures and temperatures. On the other hand, very high molecular weight and highly complex organic acids do not show similar aggressiveness towards steels under similar conditions.

⁹ MSDS for a conventional crude, 2007, <http://www.elpaso.com/msds/A0017-Crude%20Oil.pdf>

Widespread research has been completed comparing the corrosion rate of steels to the TAN of the crude. However, since the corrosion rate resulting from naphthenic acid is viewed as negligible below 400 degrees Fahrenheit, the majority of this research is done at higher temperatures.^[10] A report by Baker Hughes cites several examples of the effects of naphthenic acid corrosion on carbon steel are minimal at temperatures below 400 degrees Fahrenheit.^[11] The Supplemental Draft Environment Impact Statement , clearly states that the maximum operating design temperature for the Keystone XL Pipeline is not to exceed 150 degrees Fahrenheit^[12].The Rules and Regulations governing the transportation of Crude on the Keystone XL pipeline state that temperatures will not exceed 100 degrees Fahrenheit.^[13] Therefore there will be no corrosion risks directly related to high acidity and TAN during the transportation of a dilbit crude.

Suggested Updates to the Department of State SDEIS

In order to ensure that the information presented in the U.S. Department of State SDEIS is as accurate as possible, we have compiled a list of general comments and suggested updates related to section 3.13.5.1.

First, we would like to note that the crudemonitor.ca web site has undergone a revision since the publishing of the SDEIS. As such, the links noted in the SDEIS need to be updated as follows:

- 1) P 3-104 – the WCS assay is now located at <http://crudemonitor.ca/crude.php?acr=WCS> and the OSA assay is now located at <http://crudemonitor.ca/crude.php?acr=OSA>

¹⁰ CLI Houston Corrosion and Materials Technology, Mechanisms of naphthenic acid corrosion, <http://www.clihouston.com/news/three-mechanisms-of-naphthenic-acid-corrosion.html>

¹¹ Baker Hughes presentation on Naphthenic Acid Corrosion Control Strategies, 2006, page 13, <http://www.aiche-chicago.org/symposium06/rechtien.pdf>

¹² Supplemental Draft Environmental Impact Statement for Keystone XL, 3-112, http://www.keystonepipeline-xl.state.gov/clientsite/keystonexl.nsf/04_KXL_SDEIS.pdf?OpenFileResource

¹³ TransCanada Rules and Regulations applying to the transportation of petroleum, Article 4 Quality, http://www.transcanada.com/docs/Key_Projects/06_NEB_Tariff_No_4_Rules_and_Regs_CL.pdf

- 2) P 3-110 – the reference to <http://crudemonitor.ca/current.html> should be truncated to <http://crudemonitor.ca>

Second, a minor typo on page 3-105 should read “... and vanadium concentrations are less than 4 and less than 160 ppm respectively; ...”

While we believe that the U.S. Department of State has chosen accurate and representative comparisons of the Western Canadian Sedimentary Basin (WCSB) crudes proposed for transportation on the Keystone XL Pipeline to crudes currently being shipped, received, transported, stored, and refined in the PADD III area, we have noted that the SDEIS has referenced outdated results from a previous version of the Crude Quality Inc. and crudemonitor.ca websites. The attached tables incorporate the most recent data available (May 1, 2011) for Western Canadian Select (WCS) and Suncor Synthetic A (OSA) (see Appendix A). These revised tables should serve as replacements for 3.13.5-1 and 3.13.5-2 in the SDEIS document. We have also revised table 3.13.5-3 from the SDEIS document to reflect the current average values for WCS, OSA, and Cold Lake Blend (see Appendix B). Updating this information in the SDEIS will allow for the best possible comparison between the proposed crudes – Western Canadian Select, Suncor Synthetic crudes, and Cold Lake Blend – to crude products such as Mexican Maya, Venezuelan Bachaquero, and Venezuelan Petrozuata which are already found throughout PADD III.

Based on our independent review of the revised table 3.13.5-3, we would agree with the U.S.

Department of State’s assessment that the crudes proposed for transport on the Keystone XL pipeline have comparable properties to the heavy crudes currently available in PADD III. For example, density and sulfur in WCS and CL were fairly consistent with the same qualities in the Mexican Maya, while the TAN in WCS and CL were at or around the same level of the Venezuelan Heavy Sours. The SDEIS document, which also reports on the sediment and water content specifications enforced by the U.S. Federal Energy Regulatory Commission (FERC), indicates that the crudes proposed for transportation on

Keystone XL would meet these requirements. We would, however, challenge the statement made in the SDEIS with regards to a comparison of sediment values between conventional and oil sands derived crudes (SDEIS Keystone XL Project, 3-117 to 3-118). While the U.S. Department of State asserts that the sediment content in conventional crudes are, on average, higher than the contents for oil sands derived crudes, we would argue that this is too simplistic of a comparison. While a wider range of typical sediment values may be observed for the oil sands derived crudes than that for the conventional crudes, it would seem most appropriate to state that the sediment values for conventional and oil sands derived crudes are fairly comparable.

We believe that with the incorporation of our revised tables and updates, as suggested above, the SDEIS presented by the U.S. Department of State should be viewed as highly representative of the realities of the crude transportation for dilbit crudes.

Conclusions

In conclusion, Crude Quality Inc. supports the information and conclusions presented by the U.S. Department of State in their Supplemental Draft Environmental Impact Statement. As a fully homogeneous mixture, a dilbit will not spontaneously separate into its base components. In the absence of separation, it is impossible to state that the risks associated with the individual components will have any effect on the transportation of the blended product. Furthermore, any risks that are associated with the dilbit crude are equally applicable to conventional crude products. It is our expert opinion that dilbit blends are currently being handled in a manner consistent with their chemical and physical properties.



Crude: Western Canadian Select

Location: Hardisty

Batch: WCS-964

Sample Date: March 22, 2011

Summary Comments

Slight increases in C5s x C7s, benzene, toluene and nickel were detected for the March 22 sample of WCS. Density, TAN, and C10s were marginally decreased.

Basic Analysis Information

	March 22, 2011	5 Year Avg. +/- Std. Dev.	Avg. - Std. Dev.	Avg. + Std. Dev.
Relative Density	0.924	0.932 +/- 0.006	0.926	0.938
Gravity (degrees API)	21.6	20.6 +/- 0.8	19.8	21.4
Absolute Density (kg/m ³)	923.6	929.5 +/- 4.9	924.6	934.4
Sulphur (mass%)	3.44	3.43 +/- 0.13	3.30	3.56
MCR (mass%)	9.69	9.47 +/- 0.40	9.07	9.87
TAN (mgKOH/g)	0.78	0.89 +/- 0.11	0.78	1.00
Nickel (mg/L)	61.0	56.3 +/- 3.5	52.8	59.8
Vanadium (mg/L)	137.0	134.9 +/- 10.9	124.0	145.8

Light Ends (Vol%)

	March 22, 2011	5 Year Avg. +/- Std. Dev.	Avg. - Std. Dev.	Avg. + Std. Dev.
Propane	0.07	0.06 +/- 0.02	0.04	0.08
Butanes	2.31	2.17 +/- 0.30	1.87	2.47
Pentanes	5.83	4.05 +/- 0.64	3.41	4.69
Hexanes	4.80	3.62 +/- 0.54	3.08	4.16
Heptanes	3.13	2.64 +/- 0.35	2.29	2.99
Octanes	2.14	2.13 +/- 0.28	1.85	2.41
Nonanes	1.40	1.55 +/- 0.21	1.34	1.76
Decanes	0.58	0.73 +/- 0.12	0.61	0.85

BTEX (Vol%)

	March 22, 2011	5 Year Avg. +/- Std. Dev.	Avg. - Std. Dev.	Avg. + Std. Dev.
Benzene	0.19	0.15 +/- 0.02	0.13	0.17
Toluene	0.34	0.28 +/- 0.04	0.24	0.32
Ethyl-Benzene	0.06	0.06 +/- 0.01	0.05	0.07
Xylenes	0.29	0.29 +/- 0.04	0.25	0.33

Appendix A - Supplementary Draft EIS - TABLE 3.13.5-1 revised

crudemonitor.ca

Crude Name: Western Canadian Select
 Sample Location: Hardisty, AB
 Assay Month: December 2010

Whole Crude		Naphtha (IBP to 190°C)	
Density (kg/m ³): 929.8		Density (kg/m ³): 691.1	Butanes (vol%): 11.92
API gravity (°API): 20.60		API gravity (°API): 73.10	Pentanes (vol%): 23.80
Sulphur (□t%): 3.520		Sulphur (□t%): 0.050	Hexanes (vol%): 15.92
Nitrogen (mass ppm): 2,801.3		Nitrogen (□t%): ---	C12 Minus (vol%): 99.96
TAN (mg KOH/g): 0.91		Mass % Recovery: 14.33	Full C30+
MCRT (mass %): 9.67		Volume % Recovery: 19.24	
Nickel (mass ppm): 56.0			
Vanadium (mass ppm): 140.0			
		Distillate (190 to 343°C)	
		Density (kg/m ³): 879.9	
		API gravity (°API): 29.20	
		Sulphur (□t%): 1.220	TAN (mg KOH/g): 0.34
		Nitrogen (mass ppm): 33.1	MCRT (mass %): 0.02
		Mass % Recovery: 16.67	Nickel (mass ppm): ---
		Volume % Recovery: 17.58	Vanadium (mass ppm): ---
		Gas Oil (343 to 527°C)	
		Density (kg/m ³): 954.5	
		API gravity (°API): 16.60	
		Sulphur (□t%): 2.970	TAN (mg KOH/g): 1.66
		Nitrogen (mass ppm): 1,130.2	MCRT (mass %): 0.11
		Mass % Recovery: 26.74	Nickel (mass ppm): ND
		Volume % Recovery: 25.99	Vanadium (mass ppm): ND
		Residuum (527°C+)	
		Density (kg/m ³): 1,054.2	
		API gravity (°API): 2.61	
		Sulphur (□t%): 5.560	TAN (mg KOH/g): 0.91
		Nitrogen (mass ppm): 5,771.4	MCRT (mass %): 23.53
		Viscosity (cSt at 100°C): 55,101	Viscosity (cSt at 60°C): 9,926,852
		Mass % Recovery: 42.26	Nickel (mass ppm): ---
		Volume % Recovery: 37.19	Vanadium (mass ppm): ---

Temperature Conversion

<u>Centigrade</u>	<u>Fahrenheit</u>
190	374
343	649.4
527	980.6

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Crude: Suncor Synthetic A

Location: Edmonton

Batch: OSA-693

Sample Date: March 23, 2011

Summary Comments

The March sample of OSA had typical light ends and bulk properties. No MCR and metals were detected.

Basic Analysis Information

	March 23, 2011	5 Year Avg. +/- Std. Dev.	Avg. - Std. Dev.	Avg. + Std. Dev.
Relative Density	0.862	0.860 +/- 0.007	0.853	0.867
Gravity (degrees API)	32.7	33.1 +/- 1.3	31.8	34.4
Absolute Density (kg/m ³)	861.2	858.7 +/- 6.6	852.1	865.3
Sulphur (mass%)	0.15	0.19 +/- 0.03	0.16	0.22
MCR (mass%)	ND	ND	-	-
Nickel (mg/L)	ND	ND	-	-
Vanadium (mg/L)	ND	0.1 +/- 3.8	-3.7	3.9

Light Ends (Vol%)

	March 23, 2011	5 Year Avg. +/- Std. Dev.	Avg. - Std. Dev.	Avg. + Std. Dev.
Propane	0.02	ND	-	-
Butanes	1.85	1.76 +/- 0.42	1.34	2.18
Pentanes	2.56	2.98 +/- 0.52	2.46	3.50
Hexanes	3.44	3.98 +/- 0.70	3.28	4.68
Heptanes	3.19	3.55 +/- 0.54	3.01	4.09
Octanes	4.28	4.55 +/- 0.63	3.92	5.18
Nonanes	3.75	3.83 +/- 0.49	3.34	4.32
Decanes	1.87	2.03 +/- 0.26	1.77	2.29

BTEX (Vol%)

	March 23, 2011	5 Year Avg. +/- Std. Dev.	Avg. - Std. Dev.	Avg. + Std. Dev.
Benzene	0.04	0.05 +/- 0.03	0.02	0.08
Toluene	0.20	0.24 +/- 0.05	0.19	0.29
Ethyl-Benzene	0.14	0.15 +/- 0.02	0.13	0.17
Xylenes	0.49	0.53 +/- 0.07	0.46	0.60

Appendix A - Supplementary Draft EIS - TABLE 3.13.5-2 revised

crudemonitor.ca

Crude Name: Suncor Synthetic A
 Sample Location: Edmonton, AB
 Assay Month: February 2009

Whole Crude		Naphtha (IBP to 190°C)	
Density (kg/m ³): 856.3		Density (kg/m ³): 725.2	Butanes (vol%): ---
API gravity (°API): 33.60		API gravity (°API): 63.50	Pentanes (vol%): ---
Sulphur (wt%): 0.180		Sulphur (wt%): ND	Hexanes (vol%): ---
Nitrogen (mass ppm): 701.4		Nitrogen (wt%): ---	C12 Minus (vol%): ---
TAN (mg KOH/g): ---		Mass % Recovery: 22.93	Full C30+
MCRT (mass %): ---		Volume % Recovery: 27.02	
Nickel (mass ppm): ---			
Vanadium (mass ppm): ---			
Temperature Conversion		Distillate (190 to 343°C)	
<u>Centigrade</u>	<u>Fahrenheit</u>	Density (kg/m ³): 871.0	
190	374	API gravity (°API): 30.80	
343	649.4	Sulphur (wt%): 0.050	TAN (mg KOH/g): ---
527	980.6	Nitrogen (mass ppm): 217.6	MCRT (mass %): ---
		Mass % Recovery: 37.34	Nickel (mass ppm): ---
		Volume % Recovery: 36.64	Vanadium (mass ppm): ---
		Gas Oil (343 to 527°C)	
		Density (kg/m ³): 934.2	
		API gravity (°API): 19.80	
		Sulphur (wt%): 0.430	TAN (mg KOH/g): ---
		Nitrogen (mass ppm): 1,469.2	MCRT (mass %): ---
		Mass % Recovery: 39.73	Nickel (mass ppm): ---
		Volume % Recovery: 36.34	Vanadium (mass ppm): ---
		Residuum (527°C+)	
		Density (kg/m ³): ---	
		API gravity (°API): ---	
		Sulphur (wt%): ---	TAN (mg KOH/g): ---
		Nitrogen (mass ppm): ---	MCRT (mass %): ---
		Viscosity (cSt at 100°C): ---	Viscosity (cSt at 60°C): ---
		Mass % Recovery: ---	Nickel (mass ppm): ---
		Volume % Recovery: ---	Vanadium (mass ppm): ---

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Revised Table 3.13.5-3 Comparison of Heavy Crude Properties									
Basic Analysis	Western Canadian Select Five Year Average (Heavy Sour Dilbit)	Suncor Synthetic A (OSA) Five Year Average (Sweet Synthetic)	Mexican Maya	Venezuelan Heavy Sours (Bachaquero and Petrozuata)	Cold Lake Blend (Dilbit; Hardisty)	Dubai Heavy (Fateh)	Arabian Heavy (Safamiya)		
Density (kg/m3)	929.5 ± 4.9	858.7 ± 6.6	858.6 ± 6.6	935.9 @15°C	928.2 ± 5.1	928.4 ± 5 @15.5°C	873.5 @15°C		
Gravity (oAPI)	20.6 ± 0.8	33.1 ± 1.3	1.3 - 25.1	16.8 / 19.5	20.8 ± 0.8	30.4 - 31.1	27 - 28		
Vacuum Residue (wt%)	32	0.3	35 -- 45	59	45 -- 50	20 - 22	19		
Sulphur (wt%)	3.43 ± 0.13	0.19 ± 0.03	3.0 - 3.7	2.40 / 2.69	3.77 ± 0.09	2 - 2.13	2.9 - 3		
Hydrogen Sulphide or Mercaptan Sulphur (wt%)	Alberta Canadian L&M Crudes 0.0020% - 0.0058%	0.01%	--	--	0.00%	< 0.0001%	--		
MCR (wt%)	9.47 ± 0.40	ND	--	17.3	10.44 ± 0.37	--	--		
Bottom Sediment & Water (out) (%)	0.38% ± 0.095%	<0.5%	0.7%-1.5%	--	--	--	0.29%		
TAN (mgKOH/g)	0.89 ± 0.11	--	0.4	1.2	0.95 ± 0.11	0.05	0.4		
Salt (ptb)	40.0 ± 13.6		--	6	--	11.9 ± 3.2	--		
Mercury (mg/kg)	1.4 ± 0.3 ; 2.2 ± 0.4	3-5; 13.5	--	--	--	--	--		
Nickel (mg/L)	56.3 ± 3.5	ND	45.8 ± 7 (n=3)	55 - 84	65.2 ± 3.6	14 - 19	22 - 25		
Vanadium (mg/L)	134.9 ± 10.9	0.1 ± 3.8	267 ± 23 (n=4)	324 - 303	168.7 ± 11.4	42 - 58	70		
Olefins (wt%)	ND	ND	--	--	--	--	--		
Naphtha (wt%)	8.9	--	15	2 - 8	16	11.5 - 16	14.7		
S:A:R:A (wt%)	11% S: --: --: 33% A	--: --: --: --	23 : 35 : 15 : 27	4 : 4 : 59 : 33	--: --: --: --	--: --: --: 2% A	--: --: --: 9.6% A 5% S: --: --: 11% A		
Benzene	0.14	0.15 ± 0.02	0.05 ± 0.03	0.05	0.24 ± 0.03	6.5	0.99		
Toluene	0.25	0.27 ± 0.04	0.24 ± 0.05	0.13	0.37 ± 0.05	--	3.98		
Ethyl Benzene	0.05	0.06 ± 0.01	0.15 ± 0.02	0.07	0.05 ± 0.01	--	2.18		