6.1.2 Testing Protocols/ASTM Standards

The objective of the Gainford equipment test was to evaluate whether the current inventory of oil skimmers is suitable for recovering a common dilbit product. Each skimmer manufacturer was offered the opportunity to perform under consistent operating conditions and measurement procedures that were guided by the following ASTM standards:

F-631: Standard Guide for Collecting Skimmer Performance Data in Controlled Environments
F-2008: Standard Guide for Qualitative Observations of Skimmer Performance
F2709-08: Standard Test Method for Determining Nameplate Recovery Rate of Stationary Oil Skimmer Systems

It should be noted that each of the respective manufacturers of the devices exercised at Gainford had previously tested their units under strict adherence to ASTM standards as part of the nameplate recovery certification process. As such, it was not the intent of the Gainford study to replicate any of those prior tests. Rather, the ASTM standards referenced at Gainford were used only as guidance for the following parameters:

- Quantitative measurement of ambient conditions
- Appropriate laboratory analysis of virgin and recovered product
- Test facility design
- Test methodology
- Skimmer performance calculations

To allow vendors to correctly configure power units, check hose connections, and ensure operability prior to test commencement, vendors were given the opportunity to calibrate their equipment with the water of their respective tanks prior to the discharge of any oil.

Oil was discharged into the test tanks on May 13, and the subsequent tests followed the protocol as detailed below:

1. Allow the oil to stand for four hours prior to skimmer testing to reduce the combustible gas and benzene levels.
2. Skimmer discharge lines were plumbed so that the recovered liquids could be diverted to either a calibration cube or to the common waste tank (E6). After achieving steady state operation in the discharged oil, the subject skimmer effluent was diverted from the common waste tank (E6) to the calibration cube for a specified time (initially 30 seconds but modified in later test periods to a full 4 minutes; see modification 1 below).
3. The product in the calibration cube was allowed to settle for approximately one day after which the total liquid volume was measured. The cube was then decanted of free water. Once the water was removed the volume of the cube was again measured. An oil sample was then taken from the calibration cube sample tap and analyzed offsite for

water content according to Karl-Fischer Titration procedures (ASTM D1123). The volumetric measurements were then used to determine the skimmer's recovery capacity and efficiency.

4. The fluids accumulated in the common waste tank (E6) were allowed to settle for approximately one day. Thereafter, the water was decanted, and the remaining emulsion was gravity fed in equal amounts back to the test tanks. This procedure provided each of the skimmers with a common starting point for the next test in the sequence (see modification 2 below).

In accordance with the plan, these procedures were repeated on Day 3 (~48 hours after the initial oil release); Day 5 (~96 hours); Day 7 (~144 hours); and Day 9 (~192 hours).

On the last test day, Day 10 (~240 hours), a final test was conducted with skimmers exercised in tank E7, the weathered oil tank. The weathered oil tank (E7) was charged with 625 L (165 US gallons) of CLWB that had been poured in it on Day 1 (May 13) and left undisturbed for ten days. Originally, this last day test with 10 day weathered oil was to be a "Best in Show" exercise; however, this test was also modified (see modification 3 below) to better reflect evolving conditions.

Figure 6-3: Day 10 testing

6.1.3 Discussion of Test Modifications Made During the Test Period:

Modification 1 - Discharge Time to the Calibration Cube: The initial plan called for the tests to be conducted for a uniform 30 seconds. This duration was based on ASTM guidance and the concern that the 1 m^3 calibration cube capacity would be exceeded. After the first day of testing concluded, it was determined that the calibration cubes had sufficient capacity and that the tests could be run for longer durations. As of the second round of equipment tests (Day 3; ~48 hours), it was mutually agreed that the skimmers would run for four minutes after achieving steady state operation. This modification to the testing procedure remained consistent for the subsequent five tests.

Modification 2 - Common Waste Tank: After the first day of testing it was determined that diverting oil to the common waste tank, settling the liquids, and then redistributing that oil back to the test tanks was laborious and offered no benefit to the test. Therefore, a second protocol modification was made such that skimmer discharge – prior to diversion to the calibration cube – would no longer be directed to E6, but would now simply be recirculated back to the source tank.

Modification 3 - Last Test Day: The last test day was modified such that any vendor who wished to test their skimmer in tank E7 (10 day weathered CLWB) would be given that opportunity. Two of the vendors agreed to do so.

6.2 Oil Type and Properties

The same CLWB (winter blend) as was issued for the fate and behavior science study was chosen to be used for the equipment test. The CLWB was drawn from the pipeline in March and stored until the time of the test in closed-top drums in Edmonton, Alberta. The CLWB possessed the following properties at the beginning of the test period at Gainford:

Absolute Density (kg/m³)	925.2
Viscosity cSt @ 15 °C	220.3
Water Content (mass %)	0.43

Table 6-2: Properties of CLWB at the start of the equipment tests

Each test tank was given a measured, initial charge of three full 55 gallon drums (625 L or 165 US gallons) at the start of the test. To avoid emulsifying the oil from a plunging discharge stream, hand pumps were used to deliver the product onto a horizontal spillway resting on the surface of water. Releasing the oil into the E-series tanks took place between 1000 and 1100 on May 13.

The average thickness of the oil at the start of the test was measured to be ± 30 mm. This dimension was derived from calculations using vertical height measurements. In the interest of safety, skimmers had been pre-positioned in each tank after water depth measurements were taken but prior to discharge of the oil. This caused a perceived variation in slick thickness as a result of the different displacements of the skimming systems.

In accordance with the work plan, testing began on the first day of the release, approximately four hours after the nominal start of the spill, roughly between 1530 and 1600 on May 13.

6.3 Water Properties

Comparable to the science test tanks, the water properties of the equipment test tanks were representative of Burrard Inlet in British Columbia. The following target water conditions were determined to replicate Burrard Inlet water conditions for the purposes of this exercise:

Water Temperature	10 °C (50 °F)
Salinity	20 ppt (estuarine/brackish)
pH	7 (neutral)

Table 6-3: Water properties (target)

Site personnel were able to meet the target values for salinity and pH; however, higher than expected ambient air temperatures caused the tank water temperature to rise above the target value (see Table 6-4). Elevated water temperature was not deemed to be a significant factor in skimmer performance and realistically constituted conditions that could be experienced on Burrard Inlet surface waters during a summer day.

6.4 Equipment Tested

Under uniform conditions, the following skimming systems were tested in succession on the same days:

6.4.1 Aquaguard RBS Triton 60 DI3 Oil Skimming System

The Aquaguard system tested at Gainford was a brush skimmer driven by a diesel/hydraulic power pack. The skimmer's recovery technology uses oleophilic adhesion of the oil to the bristles of a brush rotating through the oil/water interface. A scraper removes the recovered product which is then collected in a common sump and pumped to a remote storage container.

Figure 6-4: Aquaguard RBS Triton Skimmer

Below are RBS Triton features summarized from the Aquaguard brochure:

- Stated recovery rates based on tests "witnessed by ABS Marine Services and Det Norske Veritas –tested to the ASTM-F631-93/99 standard;"
- Up to 98 percent efficiency;
- Versatile; brushes can be interchanged with either drums or discs for various oil types;
- When outfitted with the brush attachment, the recovery rate is 63 m^3/hr (396 bbl/hr).

6.4.2 Desmi DBD-5 Skimmer

The Desmi DBD-5 system was a diesel/hydraulic powered skimmer fitted with an oleophilic brush-drum assembly. The drum rotates through the oily water where oil is attracted and adheres to the brush surfaces. A scraper transfers the recovered oil into a central collection sump.

Below are DBD-5 features summarized from the Desmi brochure:

- Stated recovery rate with brushes is 7 m^3/hr (44 bbl/hr);
- This small unit has a 0.12 m or 5 inch draft suitable for use in shallow water environments

Figure 6-5: Desmi DBD-5 Skimmer

6.4.3 Lamor MultiMax LAM 50/3C Brush Skimmer

The Lamor system tested at Gainford was a stiff-brush conveyor belt type oil skimmer. The conveyor belt consists of three stiff-brush-chains. The oleophilic brush conveyor belt uses a patented brush cleaner to separate the oil from the water and lift the recovered product to the oil transfer pump.

Below are LAM 50/3C features summarized from the Lamor brochure:

- Bureau Veritas-certified recovery rate of 53.1 m^3/hr (334 bbl/hr);
- Designed to recover all types of oil with particular effectiveness in weathered oils, crude, high viscosity bunker oil, and emulsions.

Figure 6-6: Lamor MultiMax Skimmer

6.5 Results

6.5.1 Qualitative Observations and Comments

The Gainford equipment test sought to investigate the following questions:

- Does Cold Lake bitumen behave differently from other heavy crude oils commonly handled by this industry?
- Is the current inventory of skimmers, available to Trans Mountain Pipeline ULC and its contractors, capable of mechanically recovering dilbit under conditions that can be reasonably expected in the subject marine environment?
- From a recovery equipment operator's perspective, does dilbit behave differently from other crude oils you have recovered?
- Also from the operator's perspective, does the equipment get compromised in any way as a result of recovering dilbit?
- How does weathered dilbit affect equipment operation, performance, and ultimately the recovery rate?
- Can adjustments be identified to improve skimming operations of dilbit spilled on marine waters?

<u>Observations associated with the primary equipment test objective:</u>

- Throughout the allotted time period, all of the skimmers proved effective in recovering the product, whether it was fresh, emulsified, or naturally weathered after a 10 day exposure to ambient element conditions.
- There were no conditions during the testing period under which any of the three skimmers failed to operate.

<u>Peripheral observations:</u>

- At discharge the oil was less viscous than anticipated, prompting the vendors to state they would have preferred to have used oleophilic discs at the outset of the test and then switched to brushes later as the oil became more viscous.
- The oil floated throughout the 10 day period. No instances were observed of the oil's buoyancy being compromised either neutrally downward in the water column or sunken to the bottom of the tank. Visual observations of the tanks during final decontamination further affirmed the absence of sunken oil.
- Vendors and contractors both agreed that under the test conditions this dilbit behaved no differently than other crude oils and proved to be mechanically recoverable by the skimming units tested. As mentioned previously, owing to the light viscosity, recovery of the early discharged product would have been improved by the use of drum and disc skimming attachments. It was not until after a few days of weathering that the vendors would have opted to use the brush/belt attachments.

Figure 6-7: Equipment testing (Calibration Cube is to the right of Tank E5)

6.6 Weathered Oil Properties

- The data presented in Table 6-4: Summary data from equipment testing (also see Appendix H) documents the average density of the oil in the equipment test tanks starting at a value of 925.2 (absolute density at 15 °C/API 21.3) on May 13 and steadily increasing to 988.8/11.5 by May 21. These density numbers represent an average value for the oil contained in each of the three equipment test tanks over that time period. It should also be noted that this oil was not only weathering but was also being agitated and emulsified by the skimmers.
- The following density numbers for the same time period were for the undisturbed oil in tank E7 (the static tank): 925.2 kg/m^3 (API 21.3) to 975.1 kg/m^3 (API 13.5).
- Viscosities calculated (per ASTM 341) to 15 °C based on laboratory tests of oil samples collected from the tanks before skimming ranged from a starting value of 220 to over 30,000 cSt (Table 6-4).

Figure 6-8: Timed equipment test

6.7 Quantitative Data Results

Table 6-4 summarizes the conditions under which the equipment test was performed and displays a range of performance results measured during the test.

Table 6-4: Summary data from equipment testing (shown on the next two pages)

			Prior to Skimmer Testing						
Date of Test	**Duration of Peak Test**	**Number of Skimmers Tested**	**Air Temp (Avg./°C)**	**Water Temp (Avg./°C)**	**Salinity (Avg./ppt)**	**pH (Avg.)**	**Water Content in Oil Sample (lab result; mass %)**	**Density of Oil Sample (lab result; Absolute; kg/m³ @ 15 °C)**	**Viscosity of Oil Sample (lab result: cSt extrapolated to 15 °C)***
13-May	2 min	3	23.0	13.6	21.0	7.0	0.4	925.2	220
15-May	4 min	3	17.0	15.5	22.6	7.0	4.1	952.4	1252
17-May	4 min	3	14.5	17.1	20.3	7.7	8.8 - 35.5	970.1 - 985.1	6603 - 15523
19-May	4 min	3	11.8	18.9	20.0	7.6	27.7 - 41.2	982.5 - 989.9	7982 – 17234*
21-May	4 min	3	14.8	19.5	21.3	8.0	22.5 - 45.1	986.2 - 993.0	15903 – 30304
22-May	4 min	2	15.1	18.4	18.0	7.5	1.2	975.1	9642

These values were for the oil at the beginning of the test and the oil from the common discharge tank. After the modification of the test, such that skimmers were discharging into their own tanks, there was a high and low value from those three tanks.

Values are from one tank (E7) which had been left for 10 days undisturbed.

***Tank E5 extrapolated values for May 18 not included in range as curve was outlier.**

Date of Test	Approx. Elapsed Time from Oil Release that Test was Conducted (Hrs.)	Cal. Cube Avg. Settling Time (hh:mm)	Water Content in Oil Sample from Cal. Cube (lab result; %)		Total Fluid Recovered in Calibration Cube (measuring 113 cm x 92 cm; values below in cm)		Total Rate of Oil Recovery (liters/sec.)		% of Oil Content in Cal. Cube		% of Water Content in Cal. Cube	
			High	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**
13-May	4	24:00	22.0	5.7	34.0	7.5	0.86	0.21	33	19	81	66
15-May	46	19:56	91.1	8.2	16.5	14.5	0.59	0.58	95	81	18	5
17-May	96	21:03	50.4	24.1	17.7	8.1	0.70	0.31	98	79	21	2
19-May	144	21:38	47.5	20.0	39.8	10.6	0.71	0.40	94	28	72	6
21-May	192	23:40	49.0	26.2	20.0	6.1	0.82	0.25	95	79	21	5
22-May	216	22:34	17.0	13.2	8.2	2.9	0.26	0.12	97	73	27	3

This particular sample jar was almost all water and this number is an anomaly. The comparative numbers should be 11.8 (high) and 8.2 (low).

7 Recommended Future Research

7.1 Science

The experiments conducted at Gainford, combined with previous and other recent tests, have advanced the general knowledge of dilbit weathering, fate, and behavior. Recent meso-scale tank tests have encompassed different imposed energy conditions as well as freshwater to brackish water conditions. Areas for potential future investigation include:

- Sediment interaction and sinking – a series of tests to help understand the sediment/oil interaction (degree of binding or adhesion, and resulting densities). Experience from the Enbridge spill at Marshall (2010, Kalamazoo, Michigan) noted oil bound to sediment had sunk but, in many cases, was easily released back into the water column with agitation. This indirectly suggests that the weathered dilbit was not tightly bound to sediment particles.
- Effects of different diluents and bitumens – more oil weathering testing has been completed with CLB dilbit, as this is one of the predominant commodities transported; however, different diluents and source bitumens in dilbit and synthetic crude (syncrude) blends may behave differently when spilled, as well as have very different chemical characteristics and potential effects. Laboratory and meso-scale testing with additional blends would augment and broaden the knowledge base for these oils.
- Sediment penetration and flushing – a series of previous experiments were conducted by Environment Canada to determine penetration and retention of different crude oils in different sediments and under different hydraulic and environmental conditions (Harper et al., 1995; Humphrey et al., 1993). Using similar protocols, subsequent testing was conducted by Environment Canada using bitumen (Harper et al., 2002b). Additional testing, following test protocols used for the subsurface oil in coarse sediments experiment(s) (SOCSEX; Humphrey et al., 1993; Harper et al., 1995), can provide improved details on oil penetration and retention for a broader range of sediment/soil types and under different hydraulic conditions (i.e., simulated riverbed on water level drops and rises, tidal flushing). Other variables to investigate would include sediment grain size, hydraulic conditions such as water level change/ tidal flushing, and temperature and weathering state. These results could be used in conjunction with data from previous similar experiments and spill observations to describe a more accurate projection of dilbit penetration, retention, persistence, effects, and removal.
- Shoreline cleaning agents – additional testing for cleaner effectiveness using a variety of available cleaning agents is recommended. Only two cleaning agents were tested during these trials, and one proved to be effective. A more robust complement of potential cleaning agents would assist with pre-approvals should they be needed.
- Dispersant effectiveness – additional testing of dispersants using fluorometers and for different dilbit blends under variable conditions of Day 0 to Day 1 weathering will provide valuable feedback as an early countermeasure option. Additional testing using a range of dispersant to oil ratios is also suggested.

- Controlled burning – additional tests of controlled burning on various dilbit blends and a range of initial oil thicknesses will provide important information to operational feasibility and constraints as an early countermeasure.
- Biodegradation – tests to determine the effectiveness of natural and enhanced biodegradation on dilbits will provide important information on guidelines for cleanup and remediation. An understanding of biodegradation rates under different environmental conditions and using varying combinations of nutrient enrichments will assist in guiding net benefits analyses for spill cleanup.

7.2 Equipment

When the opportunity for future testing presents itself, the following situations would benefit from further investigation:

- Interchanging oleophilic discs/drums with brushes at the outset or low viscosity portion of the test period.
- Providing equipment manufacturers with oil samples for use in their respective test facilities.
- While the dilbit used at Gainford did *not* sink, certain circumstances (notably those involving fresh water and robust sediment loads) may cause heavy oils to become submerged. This phenomenon would benefit from further experimentation and study.

8 Conclusions

The overall study objective was to obtain an expanded understanding and assessment of dilbit behavior, weathering, and OSR countermeasures performance under controlled simulated conditions similar to the potential receiving environment of Burrard Inlet. This objective was achieved through the Gainford meso-scale tests. Answers to some of the fundamental questions posed regarding potential dilbit spills into a setting such as Burrard Inlet were obtained, as summarized in Table 8-1.

8.1 Scientific Testing

Specific goals were to better understand and characterize the changes in physical and chemical properties and oil distribution of dilbit in an estuarine simulated condition over a 10 day period and to determine efficiency and effectiveness of dispersant, in-situ burning, and shoreline cleaning agents as potential countermeasures for various stages of weathered oil. The Gainford tests successfully met these goals.

Both AWB and CLB dilbits exhibited properties typical of a heavy, "conventional" crude oil. In no instance was any oil observed to have sunk. Visual observations of the surface of the oil in the various tanks showed that a crust, or armoring, formed as the oil weathered. In some instances, especially noted under static conditions, the lighter components of the oil came out the oil as bubbles within the slick. These bubbles rose to the surface and, in places, became trapped under the crusted layer. Weathered oil densities approached, and in several instances, exceeded that of freshwater but not that used to represent Burrard Inlet brackish water. Visual observations were made of weathered oil overwashing within tanks with agitation; however, the weathered oil did not submerge or sink in the tanks.

Chemical analyses of the weathered oils and of the water column showed that concentrations of BTEX diminished rapidly within 48 hours and that TPH in the water column only exceeded the detection limit (2 mg/L) during the first 48 hours in tanks with moderate surface agitation, despite the artificial confinement imposed by tanks relative to what may be expected in an open, natural setting.

Countermeasures tested included dispersant application, burning, and shoreline cleaners. The visual observations of the dispersant test revealed that Corexit 9500 was marginally effective on 6 hour weathered oil and not particularly effective for more weathered CLWB dilbit. The early test burn (6 hour weathered CLWB dilbit) was effective with a sustained burn of 2 L of oil lasting for more than 2 minutes with approximately 70 percent of oil removed through burning. Additional burn testing showed approximately 50 percent of 24 hour weathered oil was removed, but only after sustained effort to ignite. The 72 hour weathered oil was not successfully ignited. Tests with Corexit 9580 found the cleaning agent to be effective on oils weathered up to five days. Test observations noted that the time oil weathers on water before being placed on the tile was less important than the time the weathered oil was exposed to air.

Comments regarding frequently asked questions (FAQs; see Table 8-1) and key points are:

- There was no two-phase separation into bitumen and diluent;

- Off-gassing of light-ends has safety implications for responders and the public during the initial hours of exposure to a release, as is the case for most oil spills;
- Both AWB and CLWB dilbits remained floating on brackish water during the 10 days of weathering;
- Both AWB and CLWB weathered dilbits surpassed viscosities of 10,000 cSt within 48 hours and exhibited strong tendencies to form a more continuous thick mat rather than a thin sheen on water which, with continued weathering and agitation, can be expected to produce tar balls.

8.2 Equipment Testing

It should be recognized that any time operators, contractors, and scientists have the opportunity to work with crude oils in an environmentally-sound field exercise, all stakeholders will benefit. As such, the Gainford equipment test delivered positive results, as summarized below:

- No performance shortcomings were observed in the current inventory of recovery equipment available to TMPL and its contractors;
- The more viscous oil encountered on test days 7, 9, and 10 caused no skimmer malfunctions including stalls, seizures, or poor recovery;
- Operational adjustments to compensate for increased dilbit viscosity were no different than field adjustments made to equipment during actual spill events for most oils;
- This particular dilbit behaved similarly to any other crude oil that the Gainford spill response professionals had experienced in the past.

Does dilbit sink in water when spilled?
Both Cold Lake Blend (CLB) and Access Western Blend (AWB) dilbits are lighter than freshwater. Dilbit spilled into fresh, brackish, or saltwater will stay on the water surface unless another mechanism mixes it into the water column, as would be the case for any oil. Only after extensive weathering may some portion become submerged or sink in freshwater, without invoking additional parameters that can modify the density of the spilled product.

Can dilbit be recovered from water using conventional spill response skimmers?
Fresh dilbit oil is much like most medium to heavy crude oils and can be recovered using a variety of skimmer systems, ranging from weirs to oleophilic units. As dilbit weathers, the oil viscosity increases significantly but skimmers designed for more viscous oils, including brush, belt, and mechanical systems, can continue to effectively recover weathered oil (demonstrated in up to 10 days of weathering in tank tests).

Can chemical dispersants be effectively used on dilbit spills?
Given appropriate safety, environmental, and operating conditions, dispersants may be effective within the first day of a spill before weathering results in oil that is too viscous to effectively disperse.

Is controlled burning a possible countermeasure for use on dilbit spills?
Given appropriate safety, environmental, and operating conditions, burning may be effective but likely for a short time period (approximately 12-24 hours) before weathering results in oil that is too viscous to effectively ignite an sustain combustion.

How toxic is dilbit relative to other crude oils?
The BTEX (benzene, toluene, ethylbenzene, and xylene) components in crude oils are some of the key chemicals of concern for toxicity. The BTEX content in CLB and AWB dilbits is approximately 1 to 1.2 percent by volume, respectively, which is slightly less than that found in Alaska North Slope or Alberta Sweet crude oils.

How variable are the weathering patterns and oil properties between different dilbits and synbits?
The Gainford tests showed that the weathering patterns between CLB and AWB are similar and that oil physical and chemical properties are consistent with other heavy crude oil. The full range of properties of dilbit blends are well known and published (see CrudeMonitor), although weathering characterization of the range of oils is the subject of ongoing research.

Can spilled dilbit be contained on water?
Lab and meso-scale tests have consistently shown both AWB and CLB dilbits to float on freshwater and saltwater. Spill containment strategies and tactics for floating oils are quite applicable to dilbit. Changes in spilled oil behavior and movement on water can be influenced by numerous factors. Effective containment requires adjusting strategies and tactics to changing conditions for a spill of any oil type.

Can spilled dilbit be effectively cleaned off shorelines?
The Gainford meso-scale tests showed that fresh to very weathered CLB can be effectively removed from a hard substrate through a combination of shoreline cleaner (Corexit 9580) and low to moderate water pressure flushing. These techniques may not be suited for all types of shorelines; however, they generally are appropriate for coarse-grained materials (gravel, cobbles, and boulders and including coarse sediment mixes).

Table 8-1: Frequently Asked Questions.

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- Mac MacCarthy, Witt O'Brien's
- Joe Verbeek, Caylen Hargreaves, and Monique Hanrahan, JVC

Appendix A: Crude Quality Inc. Data for Cold Lake and Access Western Blend

Witt O'Brien's, Polaris Applied Sciences, and
Western Canada Marine Response Corporation

What is Access Western Blend crude?

Access Western Blend (AWB) is a heavy, high TAN dilbit produced by Devon Energy Canada and MEG Energy Corp. Production is from the Athabasca region south of Fort McMurray, Alberta. Production is generated by SAGD thermal methods. Diluent is supplied to the production sites from Edmonton and dilbit is pumped back to Edmonton on the Access Pipeline. AWB is available for upgrading in the Edmonton area, and for export on the Enbridge and Kinder Morgan systems.

Light Ends Summary

Property *(vol%)*	Most Recent Sample	6 Month Average	1 Year Average	5 Year Average
C3-	0.02	0.02	0.03	0.03
Butanes	0.37	0.45	0.55	0.68
Pentanes	7.17	8.47	8.48	8.38
Hexanes	6.31	6.68	6.81	6.78
Heptanes	4.28	4.01	4.15	4.33
Octanes	2.31	2.18	2.27	2.55
Nonanes	0.90	1.02	1.09	1.23
Decanes	0.41	0.48	0.52	0.53

BTEX

Property *(vol%)*	Most Recent Sample	6 Month Average	1 Year Average	5 Year Average
Benzene	0.25	0.28	0.30	0.29
Toluene	0.44	0.46	0.49	0.50
Ethyl Benzene	0.04	0.05	0.05	0.06
Xylenes	0.29	0.33	0.35	0.39

Most Recent Sample Comments: AWB-803, Sep 20, 2013

Last 6 Samples

On a seasonally adjusted basis, Access Western Blend was consistent with historical averages for the month of September.

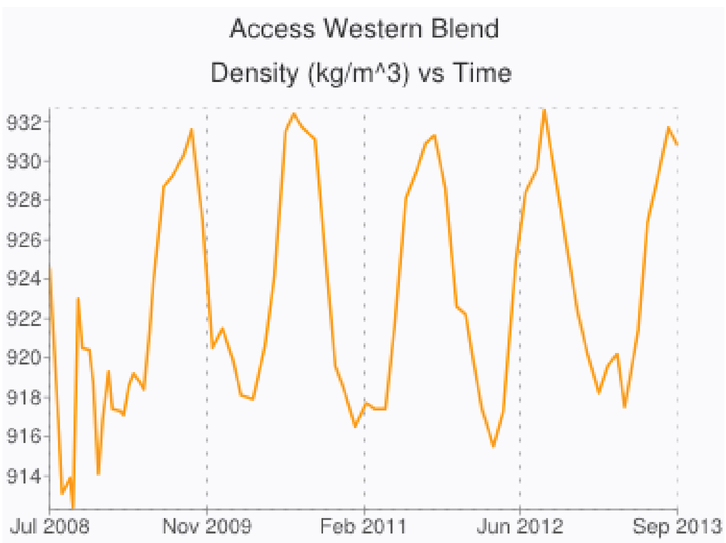
Monthly Reports

Basic Analysis

Property	Most Recent Sample	6 Month Average	1 Year Average	5 Year Average
Density *(kg/m³)*	930.8	925.3	923.6	922.7
Gravity *(°API)*	20.4	21.3	21.6	21.7
Sulphur *(wt%)*	4.12	4.01	3.95	3.94
MCR *(wt%)*	11.00	10.79	10.65	10.65
Sediment *(ppmw)*	-	94	89	193
TAN *(mgKOH/g)*	1.77	1.73	1.72	1.70
Salt *(ptb)*	-	4.7	6.4	6.4
Nickel *(mg/L)*	77.0	76.6	73.8	72.4
Vanadium *(mg/L)*	206.0	202.0	196.7	194.1
Olefins *(wt%)*	-	-	ND	ND

*ND indicates a tested value below the instrument threshold.

Trend Charts



e-mail: Crude Quality Inc.
phone: +1 (780) 757-9909
#201, 17850 105 Avenue
Edmonton, Alberta Canada T5S 2H5

Access Western Blend (AWB)

Basic Analysis

	Feb 23, 2013 Sample	5 Year Average (prior to Feb 23, 2013 sample)
Density *(kg/m³)*	919.6	922.2 ± 5.5
Gravity *(ºAPI)*	22.2	21.8 ± 0.9
Sulphur *(wt%)*	3.82	3.94 ± 0.10
MCR *(wt%)*	10.50	10.66 ± 0.50
TAN *(mgKOH/g)*	1.77	1.70 ± 0.12
Nickel *(mg/L)*	66.0	71.8 ± 4.9
Vanadium *(mg/L)*	197.0	193.2 ± 11.9

Light Ends

	Feb 23, 2013 Sample	5 Year Average
C3- *(vol%)*	0.05	0.03 ± 0.01
Butanes *(vol%)*	0.69	0.70 ± 0.14
Pentanes *(vol%)*	8.42	8.41 ± 1.20
Hexanes *(vol%)*	6.74	6.80 ± 0.68
Heptanes *(vol%)*	4.23	4.36 ± 0.48
Octanes *(vol%)*	2.56	2.58 ± 0.42
Nonanes *(vol%)*	1.29	1.25 ± 0.24
Decanes *(vol%)*	0.54	0.54 ± 0.12

BTEX

	Feb 23, 2013 Sample	5 Year Average
Benzene *(vol%)*	0.28	0.29 ± 0.03
Toluene *(vol%)*	0.50	0.50 ± 0.07
Ethyl Benzene *(vol%)*	0.06	0.06 ± 0.01
Xylenes *(vol%)*	0.39	0.39 ± 0.08

Source: http://www.crudemonitor.ca/crude.php?acr=AWB

What is Cold Lake crude?

The main players in the Cold Lake oil sands deposit are Imperial Oil Resources, Cenovus Energy, Canadian Natural Resources Limited and Shell Energy. Cold Lake production is bitumen based and requires the use of steam to release the bitumen from the underground reservoirs, and the use of diluents to meet pipeline viscosity and density specifications.

Light Ends Summary

Property*(vol%)*	Most Recent Sample	6 Month Average	1 Year Average	5 Year Average
C3-	0.02	0.03	0.04	0.04
Butanes	0.69	0.82	0.85	1.01
Pentanes	8.06	6.53	6.29	6.25
Hexanes	5.50	5.30	5.52	5.33
Heptanes	2.85	3.31	3.42	3.36
Octanes	1.36	2.04	2.18	2.21
Nonanes	0.79	1.32	1.38	1.33
Decanes	0.42	0.71	0.71	0.63

BTEX

Property*(vol%)*	Most Recent Sample	6 Month Average	1 Year Average	5 Year Average
Benzene	0.20	0.23	0.24	0.23
Toluene	0.28	0.40	0.41	0.39
Ethyl Benzene	0.02	0.05	0.06	0.06
Xylenes	0.15	0.32	0.34	0.33

Most Recent Sample Comments: CL(E)-732, Sep 21, 2013

Last 6 Samples

As expected, based on the seasonality of Cold Lake, density is slightly elevated, while light ends and BTEX are reduced for this September sample at Edmonton.

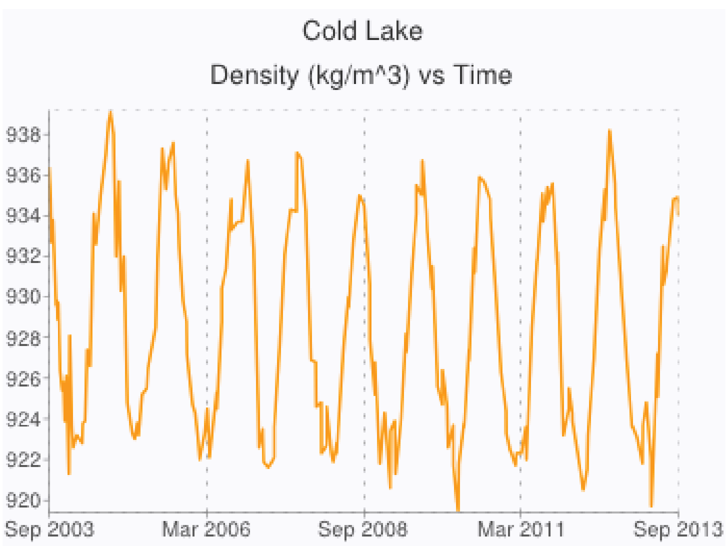
Monthly Reports

Basic Analysis

Property	Most Recent Sample	6 Month Average	1 Year Average	5 Year Average
Density *(kg/m³)*	934.0	930.0	927.9	928.1
Gravity *(°API)*	19.9	20.5	20.9	20.8
Sulphur *(wt%)*	3.91	3.83	3.79	3.80
MCR *(wt%)*	10.90	10.57	10.43	10.48
Sediment *(ppmw)*	175	119	104	162
TAN *(mgKOH/g)*	0.96	0.98	0.98	0.98
Salt *(ptb)*	7.8	8.5	9.6	11.6
Nickel *(mg/L)*	68.0	69.1	66.0	65.6
Vanadium *(mg/L)*	172.0	180.2	174.5	171.1
Olefins *(wt%)*	-	ND	ND	ND

*ND indicates a tested value below the instrument threshold.

Trend Charts



e-mail: Crude Quality Inc.
phone: +1 (780) 757-9909
#201, 17850 105 Avenue
Edmonton, Alberta Canada T5S 2H5

Cold Lake (CL)

Basic Analysis

	Feb 28, 2013 Sample	5 Year Average (prior to Feb 28, 2013 sample)
Density *(kg/m³)*	923.7	928.0 ± 5.1
Gravity *(°API)*	21.6	20.9 ± 0.8
Sulphur *(wt%)*	3.68	3.80 ± 0.08
MCR *(wt%)*	10.10	10.46 ± 0.33
TAN *(mgKOH/g)*	1.00	0.98 ± 0.08
Nickel *(mg/L)*	60.0	65.3 ± 3.0
Vanadium *(mg/L)*	170.0	169.8 ± 12.5

Light Ends

	Feb 28, 2013 Sample	5 Year Average
C3- *(vol%)*	0.04	0.04 ± 0.01
Butanes *(vol%)*	0.60	1.05 ± 0.24
Pentanes *(vol%)*	5.84	6.18 ± 0.95
Hexanes *(vol%)*	5.58	5.30 ± 0.64
Heptanes *(vol%)*	3.60	3.34 ± 0.45
Octanes *(vol%)*	2.54	2.22 ± 0.40
Nonanes *(vol%)*	1.68	1.34 ± 0.27
Decanes *(vol%)*	0.78	0.62 ± 0.14

BTEX

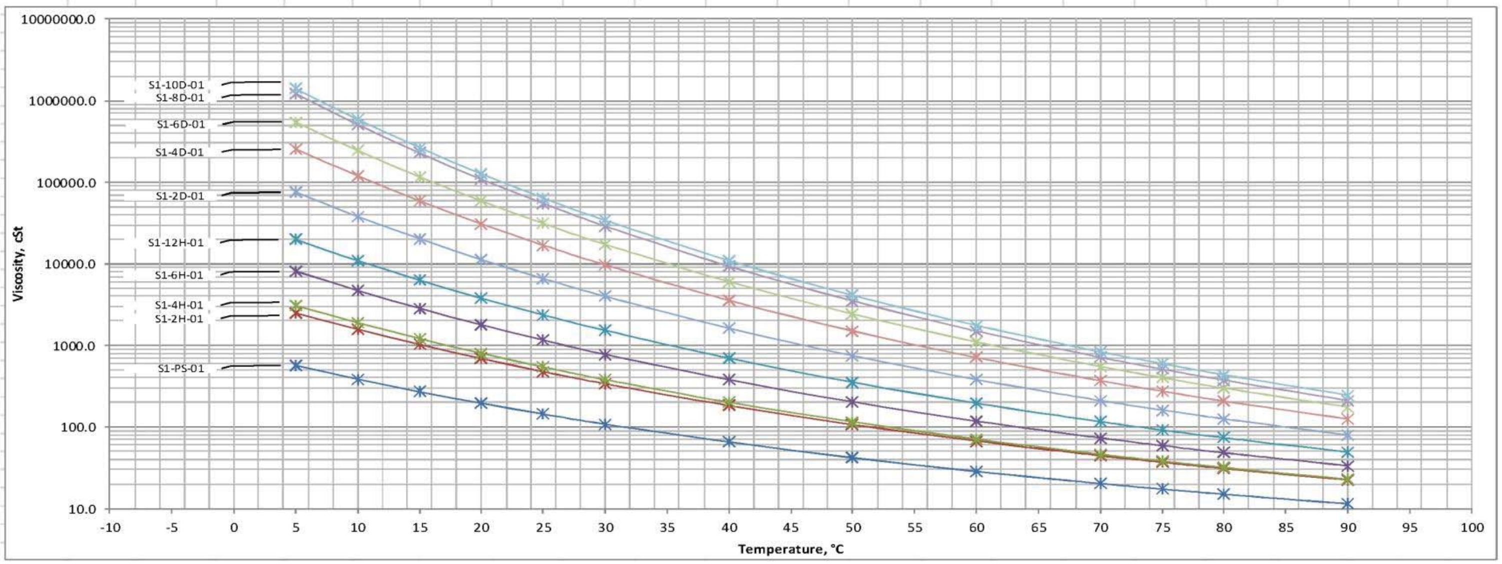
	Feb 28, 2013 Sample	5 Year Average
Benzene *(vol%)*	0.25	0.23 ± 0.03
Toluene *(vol%)*	0.46	0.39 ± 0.06
Ethyl Benzene *(vol%)*	0.07	0.05 ± 0.01
Xylenes *(vol%)*	0.42	0.33 ± 0.06

Source: http://www.crudemonitor.ca/crude.php?acr=CL

Appendix B: Oil Physical Data

Witt O'Brien's, Polaris Applied Sciences, and
Western Canada Marine Response Corporation

Job #	Sample #	Sample Point	API	Absolute Density @ 15°C kg/m3	Relative Density	Viscosity, cSt (shaded areas denote calculated values)													Pour Point	Flash Point	Water
						5	10	15	20	25	30	40	50	60	70	75	80	90	°C	°C	wt%
B338178	GJ6334	S1-PS-01	22.2	920.1	0.9209	565.8	385.6	270.5	194.9	143.8	108.3	65.36	41.92	28.49	20.26	17.34	14.97	11.43	-21	<-35	3.4
B338178	GJ6336	S1-2H-01	18.4	943.4	0.9443	2504	1575	1026	689.5	477.0	338.5	183.4	107.2	67.17	44.51	36.90	30.93	22.38	-18	<-35	6.7
B337952	GJ4821	S1-4H-01	17.9	946.2	0.9471	3081	1896	1210	799.0	543.8	380.6	200.7	115.2	70.95	46.37	38.22	31.86	22.85	-12	<-35	5
B338173	GJ6324	S1-6H-01	15.9	959	0.9599	8128	4707	2844	1781	1158	775.39	378.2	203.0	118.0	73.42	59.18	48.33	33.38	-12	<-35	5.1
B338179	GJ6340	S1-12H-01	14.6	967.4	0.9683	19782	10910	6296	3786	2363	1527	696.1	353.3	195.3	116.2	91.84	73.62	49.16	-6	<-35	0.78
B338894	GK3237	S1-1D-01	12.7	980.7	0.9816															<-35	8.3
B338894	GK3242	S1-2D-01	12.9	979.1	0.98	75560	38119	20269	11304	6584	3990	1626	748.3	380.8	211.0	161.5	125.7	79.57	6	-10	1
B340447	GL0002	S1-4D-01	11.7	987.3	0.9882	256290.7	119528.3	59125.5	30851.5	16899.0	9674.8	3565.9	1504.0	710.3	369.3	274.4	207.5	125.4	6	20	1.2
B340457	GL0063	S1-6D-01	10.7	994	0.9949	544443	244203	116477	58744	31169	17320	6047	2432	1101	552.5	402.8	298.8	176.2	12	22	1.6
B340457	GL0051	S1-8D-01	10.2	997.9	0.9988	1219579	510057	228350	108741	54768	29027	9334	3505	1499	716.2	510.7	374.8	211.4	12	52	1.7
B341627	GL8592	S1-10D-01	9.8	1000	1.001	1399367	589297	265263	126848	64087	34040	10969	4119	1758	834.8	599.5	435.3	245.7	9	58	4.5



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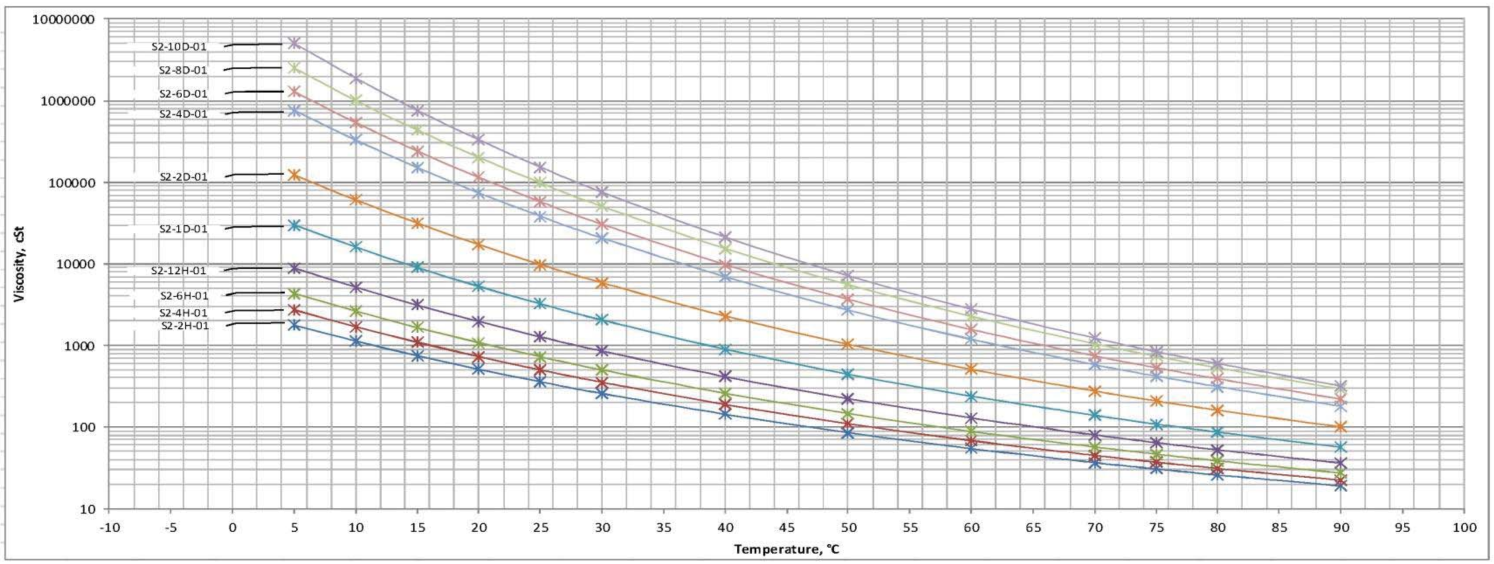
Job #	Sample #	Sample Point	API	Absolute Density @ 15°C kg/m3	Relative Density	Viscosity, cSt (shaded areas denote calculated values) 5	10	15	20	25	30	40	50	60	70	75	80	90	Pour Point °C	Flash Point °C	Water wt%
B338178	GJ6337	S2-2H-01	19.5	936.5	0.9373	1769	1132	749.0	511.1	358.6	257.3	143.6	85.24	54.50	36.70	30.65	25.87	18.95	-24	<-35	0.22
B337952	GJ4822	S2-4H-01	18.4	942.9	0.9438	2733	1703	1097	731.4	502.0	354.1	189.2	109.7	68.20	44.90	37.13	31.05	22.37	-27	<-35	0.93
B338173	GJ6325	S2-6H-01	17.4	949.7	0.9506	4345	2634	1658	1082	726.5	502.8	259.5	146.1	88.44	56.92	46.59	38.58	27.33	-18	<-35	0.18
B338179	GJ6342	S2-12H-01	16	958.4	0.9593	8927	5176	3128	1962	1274	853.1	415.6	222.6	129.1	80.10	64.48	52.58	36.22	-15	<-35	4.2
B338894	GK3238	S2-1D-01	14.1	971.2	0.9721	29945	16054	9027	5300	3237	2050	901.8	444	239.1	139.2	108.9	86.49	56.81	3	<-35	0.5
B338894	GK3243	S2-2D-01	12.3	983	0.9839	123088	60645	31539	17227	9839	5858	2304	1031	510.6	276.4	209.3	161.2	100.2	12	-13	0.9
B340447	GL0003	S2-4D-01	10.5	995.7	0.9966	761236	328775	151596	74170	38297	20767	6955	2704	1191	581.9	422.1	313	179.7	9	5	3.7
B340457	GL0064	S2-6D-01	13.1	978	0.9789	1290365	539180	241152	114716	57714	30553	9802	3672	1567	744.8	533.3	390.6	219.8	9	24	5.8
B340457	GL0052	S2-8D-01	9.6	1002	1.003	2501399	1008067	435942	200980	98201	50652	15414	5549	2277	1048.3	738.2	531.5	292.5	15	24	6.3
B341627	GL8594	S2-10D-01	8.4	1010	1.011	5031495	1885557	763943	332161	153972	75647	21299	7153	2784	1232	839.2	602.1	320.2	12	75	18.2



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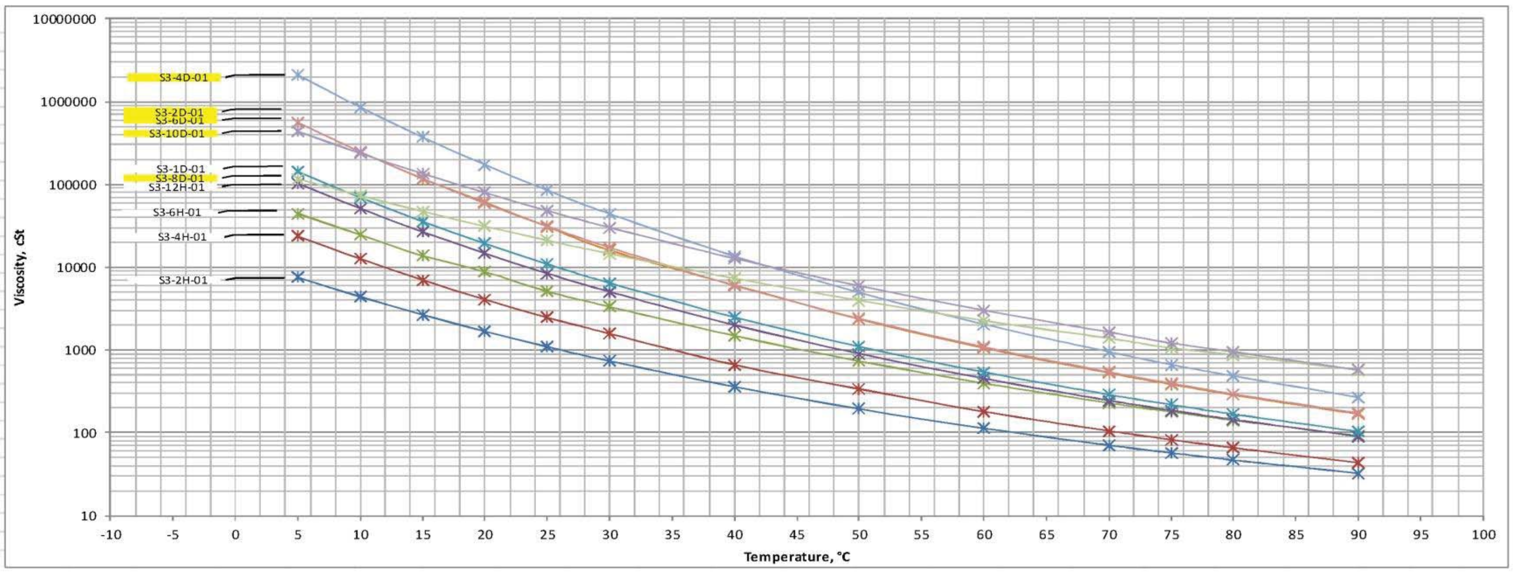
Job #	Sample #	Sample Point	API	Absolute Density @ 15°C kg/m3	Relative Density	Viscosity, cSt (shaded areas denote calculated values) 5	10	15	20	25	30	40	50	60	70	75	80	90	Pour Point °C	Flash Point °C	Water wt%
B338178	GJ6338	S3-2H-01	16.3	956.3	0.9572	7554	4394	2665	1676	1093	734.3	360.3	194.3	113.5	70.85	57.20	46.79	32.41	-6	<-35	8.6
B337952	GJ4823	S3-4H-01	14.4	969.1	0.97	23801	12581	6994	4070	2468	1577	663.3	338.2	180.4	105.4	82.68	65.86	43.53	-6	<-35	25.3
B338173	GJ6326	S3-6H-01	12.9	979.2	0.9801	44568	24517	13766	8778	5099	3329	1487	734.9	395.9	229.5	178.9	141.6	92.14	0	-3	24.1
B338179	GJ6344	S3-12H-01	12.4	982.4	0.9833	103273	51157	26746	14685	8430	5044	2002	904	451.4	246.2	187.1	144.6	90.42	3	-3	
B338894	GK3239	S3-1D-01	12.1	984.2	0.9851	142304	69245	35607	19251	10893	6433	2491	1102	540.1	289.8	218.6	167.8	103.7	3	4	42.4
B338894	GK3244	S3-2D-01	10.5	995.8	0.9967	559158	248150	117267	60820	30909	16000	6078	2356	1061	528.8	386.0	287.3	168.0	15	3	42.5
B340447	GL0004	S3-4D-01	10.3	997.2	0.9981	2102287	853772	371916	172648	84910	44013	13595	4928	2043	950.6	667.6	485.5	268.5	6	25	45.3
B340457	GL0065	S3-6D-01	10.8	993.7	0.9946	554916	247529	117493	59006	31192	17277	6000	2403	1085	541.4	396.1	294.5	172.4	15	25	3.4
B340457	GL0053	S3-8D-01	11.1	991.2	0.9921	116304	73063	47117	31132	21040	14521	7324	3955	2266	1385	1057	875	569.5	12	26	52
B341627	GL8596	S3-10D-01	8.9	1007	1.008	436198	238100	135014	79295	48103	30067	12738	5936	3003	1645	1211	950.2	575.1	12	20	43.4



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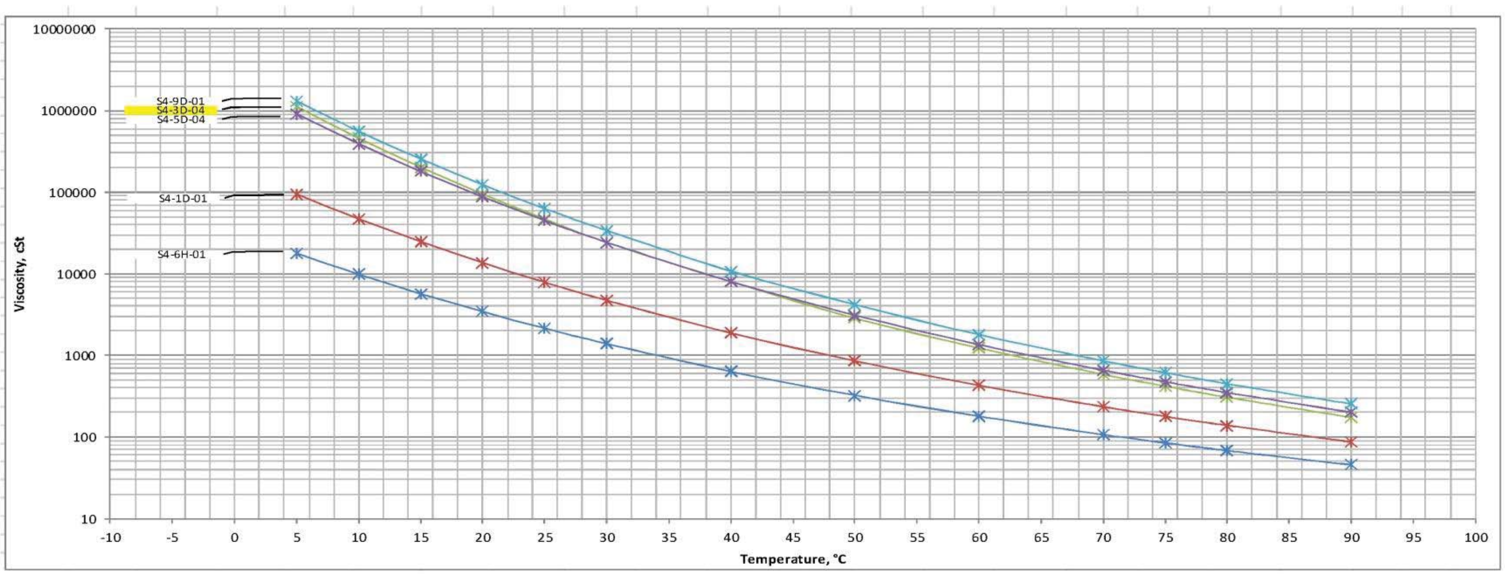
Job #	Sample #	Sample Point	API	Absolute Density @ 15°C kg/m3	Relative Density	Viscosity, cSt (shaded areas denote calculated values) 5	10	15	20	25	30	40	50	60	70	75	80	90	Pour Point °C	Flash Point °C	Water wt%
B338894	GK3240	S4-6H-01	14.3	969.9	0.9708	17897	9876	5703	3433	2145	1390	633.4	323.6	179.3	107.1	84.76	68.06	45.60	3	-12	4.1
B338894	GK3241	S4-1D-01	12.1	984.2	0.9851	94829	47175	24762	13647	7861	4724	1881	856.1	429.1	235.0	178.9	138.5	86.92	15	4	3.5
B339476	GK3579	S4-3D-04	10.2	997.7	0.9986	1119504	458023	201284	94369	46915	24200	8018	2856	1231	585.9	419.3	306.6	173.9	9	56	33.4
B340457	GL0047	S4-5D-04	10.3	997.3	0.9982	910030	391264	179587	87465	44957	24269	8056	3105	1357	658.7	475.6	350.7	200.6	9	>100	42.9
B341322	GL6305	S4-9D-01	8.7	1008	1.009	1308356	558571	254489	122999	62728	33930	10780	4199	1792	857.9	614.5	449.4	254.2	12	72	36.8



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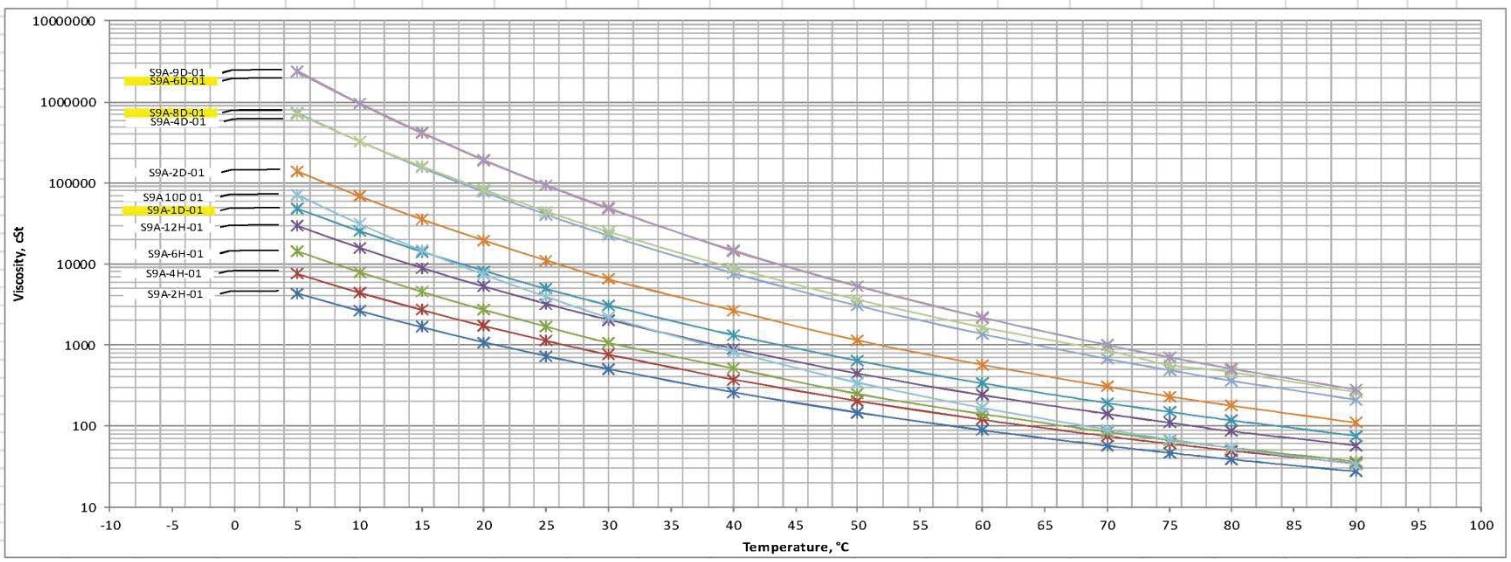
Job #	Sample #	Sample Point	API	Absolute Density @ 15°C kg/m3	Relative Density	Viscosity, cSt (shaded areas denote calculated values) 5	10	15	20	25	30	40	50	60	70	75	80	90	Pour Point °C	Flash Point °C	Water wt%
B339476	GK3570	S9A-2H-01	16.5	954.9	0.9558	4352	2638.4	1661.2	1082.5	727.8	503.3	259.9	146.2	88.52	56.97	46.63	38.62	27.35	-15	<-35	1.6
B339476	GK3573	S9A-4H-01	15.8	959.7	0.9606	7545	4429	2706	1715	1124	759.3	375.2	203.7	119.4	74.76	60.43	49.47	34.30	-9	<-35	1.4
B339476	GK3576	S9A-6H-01	14.9	965.8	0.9667	14445	7891	4521	2705	1683	1064.0	513.6	248.1	140.3	84.17	66.80	53.79	36.25	-21	<-22	2.5
B340447	GK9996	S9A-12H-01	13.8	973.3	0.9742	29470	15846	8933	5257	3217	2040	901.5	444.2	239.7	140.7	109.4	85.86	57.48	-6	-3	5.1
B340447	GL0005	S9A-1D-01	12.7	980.4	0.9813	48169	25475	14133	8189	4936	3085	1326.8	637.4	336.20	191.6	149	116.9	75.57	-3	15	8.5
B340457	GL0044	S9A-2D-01	11.3	989.7	0.9906	139303	68581	35626	19433	11081	6471	2664	1133.0	566.9	305.5	230.78	177.37	109.76	-6	32	11.4
B340457	GL0057	S9A-4D-01	10.5	995.9	0.9968	732684	325804	154077	77057	40551	22353	7685	3046	1360	673.3	488.3	360.7	209.9	0	70	39.6
B341322	GL6302	S9A-6D-01	9.9	999.7	1.0010	2352536	949342	411114	189800	92871	47911	14673	5280	2175	1003.0	708.5	509.8	281.4	12	26	40.2
B342051	GM1610	S9A-8D-01	9.6	1002.0	1.0030	706335	326380	159600	82177	44353	24991	8900	3620	1648	853.8	563.9	462.5	260.9	9	73	36.1
B343405	GM9752	S9A-9D-01	10.4	996.5	0.9974	2407676	967975	417801	192325	93863	48920	14410	5342	2173	1001	705.2	508.0	279.9	24	71	24.6
B343410	GM9767	S9A 10D 01	10.4	996.5	0.9974	71113	31084	14634	7362	3931	2188	826	341.7	167.4	90.22	68.49	53.02	33.46	21	>100	35.9



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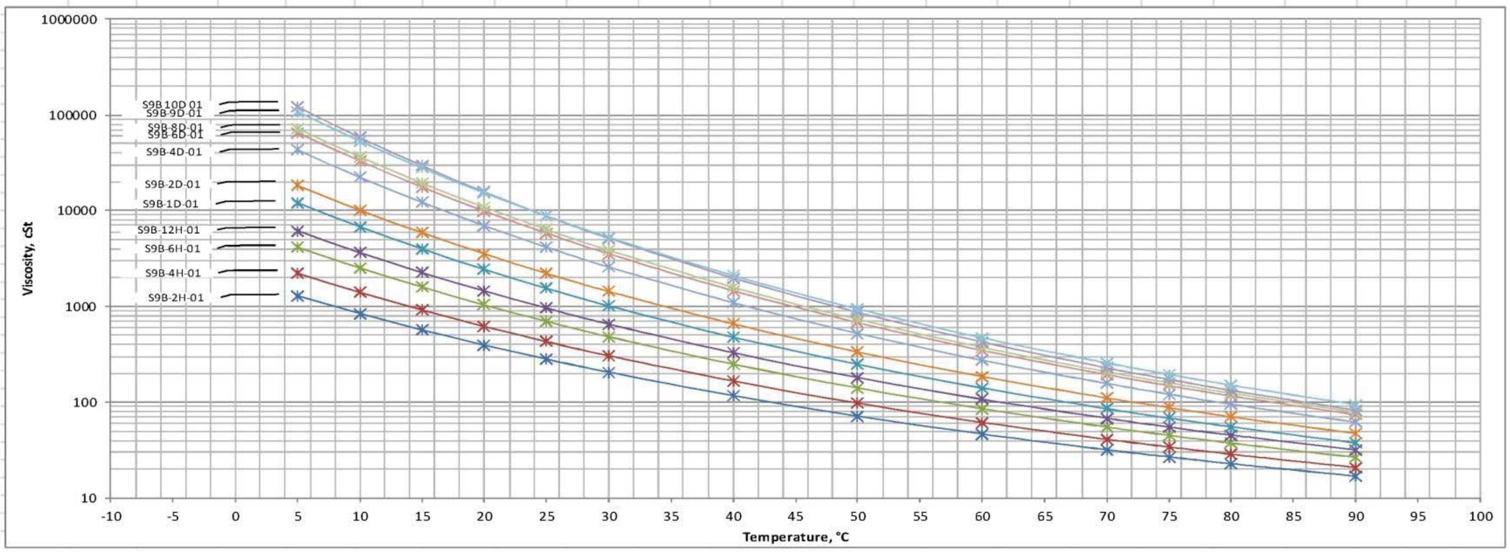
Job #	Sample #	Sample Point	API	Absolute Density @ 15°C kg/m3	Relative Density	Viscosity, cSt (shaded areas denote calculated values) 5	10	15	20	25	30	40	50	60	70	75	80	90	Pour Point °C	Flash Point °C	Water wt%
B339476	GK3571	S9B-2H-01	19.0	939.4	0.9402	1290	842.6	568.2	394.5	281.2	205.5	116.5	71.4	46.37	31.74	26.70	22.68	16.82	-30	<-35	1.4
B339476	GK3574	S9B-4H-01	17.9	946.1	0.9470	2220	1400	914.6	616.5	427.7	304.7	165.5	97.5	61.35	40.83	33.93	28.50	20.70	-21	<-35	1.2
B339476	GK3577	S9B-6H-01	16.6	954.8	0.9557	4151	2518	1586	1034.0	695.6	481.5	248.9	140.3	85.07	54.84	44.92	37.23	26.40	-15	<-20	2
B340447	GK9997	S9B-12H-01	16.0	958.7	0.9596	6140	3649	2255	1445	956.0	651.6	327.5	180.2	106.9	67.73	54.82	45.22	31.58	-9	<-15	0.8
B340447	GL0006	S9B-1D-01	15.5	961.8	0.9627	12090	6788	3985	2436	1545	1013	475.9	247.5	140.16	85.27	68.01	55.08	37.43	-6	-27	0.6
B340457	GL0045	S9B-2D-01	14.3	969.7	0.9706	18340	10137	5862	3532	2210	1430	655.4	333.4	185.0	110.4	87.41	70.16	46.98	-9	24	1.6
B340457	GL0058	S9B-4D-01	13.4	975.6	0.9765	42904	22287	12179	6968	4156	2575	1094	521.3	273.8	156.3	120.9	94.9	61.7	-6	25	1.4
B341322	GL6303	S9B-6D-01	12.9	979.2	0.9801	65127	33065	17687	9921	5809	3538	1456	675.6	346.5	193.4	148.4	115.9	73.78	6	5	1.1
B342051	GM1611	S9B-8D-01	12.7	980.3	0.9812	71985	36457	19454	10885	6358	3863	1582	730.7	373.1	207.2	159.1	123.7	78.52	9	34	0.8
B343405	GM9753	S9B-9D-01	12.5	982.0	0.9829	121634	58121	29440	15720	8806	5153	1980	867.8	424.8	227.7	172.8	132.2	82.10	15	34	2.2
B343410	GM9769	S9B 10D 01	13.5	975.2	0.9761	107913	53482	27968	15357	8815	5268	2095	942.6	470.4	256.1	194.7	150.2	93.84	12	35	1.9



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Maxxam

Job #	Sample #	Sample Point	API	Absolute Density @ 15°C kg/m3	Relative Density	Viscosity, cSt (shaded areas denote calculated values) 5	10	15	20	25	30	40	50	60	70	75	80	90	Pour Point °C	Flash Point °C	Water wt%
B339476	GK3572	S9C-2H-01	18.7	941.5	0.9423	1457	944.7	632.7	436.5	309.3	224.7	126.4	76.8	49.34	33.71	28.24	20.48	17.67	-21	<-35	1.2
B339476	GK3575	S9C-4H-01	17.9	946.2	0.9471	2279	1435	935.8	629.9	436.4	310.4	168.4	98.9	62.15	41.31	34.30	28.80	20.90	-18	<-35	1
B339476	GK3578	S9C-5H-01	16.9	952.4	0.9533	3731	2278	1443	946.4	640.0	445.0	232.1	131.8	80.41	52.12	42.79	35.54	25.31	-18	<-35	1.8
B340447	GK9998	S9C-12H-01	15.3	963.2	0.9641	14881	8210	4744	2859	1790	1160	533.8	272.9	152.4	92.02	72.71	58.03	39.63		-10	1.5
B340447	GL0007	S9C-1D-01	12.1	984.4	0.9853	17189	9645	5653	3446	2178	1422	662	340.6	190.8	114.76	90.71	73.27	49.19	-3	-10	1.7
B340457	GL0046	S9C-2D-01	12.3	983.4	0.9843	102728	50758	26479	14511	8317	4965	1972	886.9	442.8	241.4	183.4	141.7	88.62	3	31	2.3
B340457	GL0059	S9C-4D-01	10.9	992.5	0.9934	341675	156234	75896	38950	21012	12078	4318	1760.0	816.8	418.3	308.6	231.9	138.6	0	23	7.3
B341322	GL6304	S9C-6D-01	10.4	996.3	0.9972	564933	249604	117498	58584	30776	16954	5837	2322.9	1044	520.1	378.2	282.3	164.7	9	73	9.7
B342051	GM1612	S9C-8D-01	10.0	998.9	0.9998	6344773	2068867	743871	291988	124022	56559	14171	4382.8	1612	697.1	450.8	332.8	172.9	12	75	19.4
B343405	GM9754	S9C-9D-01	10.2	997.7	0.9986	1085349	444814	195792	91931	45767	24027	7622	2839.5	1210	575.2	415.1	301.5	171.6	21	70	
B343405	GM9756	S9C-9D-02	10.8	993.7	0.9946	1961612	753302	312862	139462	66274	33374	9862	3469.6	1411	652.2	451.2	331.4	182.5	15	>100	42.7
B343410	GM9771	S9C-10D-01	10.3	996.8	0.9977	1718368	695755	302527	140321	69013	35798	11092	4040.4	1685	789.6	555.4	406.1	226.0	21	>100	22.3