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Catalytic cracking of deasphalted non-conventional residues.

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## 1. Summary.

This work studies the deasphalting characteristics of residues in order to know if they are appropriate as catalytic cracking feedstock.

The overall results from this study showed similar trends to literature data reported for conventional residuums. DA oil yield and quality can be correlated with feedstock quality, solvent selection and operating conditions. Furthermore, DA oil composition can be used to estimate catalytic cracking yields and evaluate the suitability of the material as a feedstock to an FCCU.

Two typical non-conventional residuums from Athabasca Bitumen and Lloydminster were selected for this study. These oils were deasphalted using four solvents (propane, n-butane, n-pentane and n-heptane) over a range of solvent/oil ratios and temperatures. Selected DA oils were catalytically cracked over a range of severities using a modified MAT reactor and a commercial equilibrium catalyst.

By deasphalting, the data shows that as the solvent molecular weight is decreased from n-heptane through to propane, the DA oil yield decreases, the Conradson carbon and metals content of the DA oil decreases, the density decreases and the oil content of the DA oil increases.

As the DA oil quality increases and at a nominal MAT C/O ratio of 4, the coque and gas make decrease, while the gasoline, C3+C4 and LCO yields increase. There is also a good correlation between the CCR and resin content of a DAO and the coque and gas produced. In addition the gasoline yield correlates with the oil content in the DA oil.



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## 2. Introduction.

Refineries are presently limited to the amount of heavy oil that they can accept for processing and tar sands bitumen is presently upgraded commercially by coking the raw bitumen and hydrotreating the liquid products.

A number of other processes involving hydrogen addition rather than carbon rejection, have been evaluated on a semi-commercial scale for both bitumen and heavy oil upgrading. High pressure catalytic hydrocracking technology has recently been installed in one plant and is presently the process of choice for future development.

### 2.1. Solvent Deasphalting.

In this process the solvent extracts the oil fraction from the vacuum tower bottoms (VTB) leaving the asphaltenes in the residuum. The resins are partitioned between solvent selection and operating conditions. Light solvents such as propane produce high quality deasphalted oils with low Conradson Carbon Residue and a low metals content. As the solvent molecular weight increases, the DA oil quality decreases but the DA oil yield increases. Extraction temperature (or reduced temperature) can also be used within limits to control DA oil quality, with the higher temperature producing a lower yield of superior quality DA oil. In addition, increasing the solvent to oil ratio increases both the oil yield and quality of the DA oil and the operating expense.

Newer units use supercritical solvent recovery techniques<sup>1</sup> to improve process economics by minimizing energy consumption.

Correlation of the mass of asphaltene precipitated from Athabasca bitumen with the solubility parameter of the precipitating solvent was noted by Mitchell and Speight<sup>13</sup>. More recently, Hirschberg<sup>14</sup> and coworkers used the modified Flory-Huggins equation to calculate asphaltene flocculation from light crudes under gas injection. A similar approach was followed by Mansoori, Jiang and Kawanaka<sup>15</sup> in their model for predicting the onset of asphaltene deposition, with modifications to account for the heterogeneity of both the polymer and the solvent constituents in solution.

### 2.2. Catalytic Cracking.

Data in the Literature on the crackability of DA oils in an FCC unit is limited, as in the case of deasphalting, to materials derived from conventional crude oils<sup>2</sup>. It has been reported that propane DA oils are excellent feedstocks for conventional FCC

units, butane DA oils can be processed neat but throughput may be limited by the unit's coke burning capacity, while pentane DA oils require dilution with gas oils or hydrotreating prior to cracking.

For DA oils derived from unconventional oils, it may be more appropriate to consider cracking in a residual oil FCC<sup>3</sup>. These units are designed to handle the high coke and gas make generated by cracking residual oils. The DA oil quality in terms of Conradson Carbon Residue and metals (Ni and V) content would not be blended with gas oils to produce a standard feed for the FCC unit.

The new designs of residual oil FCC units claim to be able to handle feedstocks containing up to nearly 50 ppm of metals and 8-10 wt% Conradson Carbon Residue<sup>4</sup>. It is anticipated that if there is a continuing economic incentive to crack residual oils then these limits will be increased.

The crackability of heavy fractions is the subject of some controversy. One opinion is that 100% of the Conradson Carbon Residue in the feed is yielded as coke in the FCC reactor<sup>5</sup> for all commercial FCC units. Another opinion is that with proper feed/catalyst contacting there is no casual relationship between coke and carbon residue<sup>3</sup>. This author recommends the following to minimize coke formation:

- . High temperatures to promote rapid vaporization and "shattering" of asphaltenes.
- . Atomized oil injection to maximize the rate of heat transfer and cracking.
- . Minimum of backmixing.
- . A short contact time.

Literature data on the cracking of residual feedstocks offers following comparisons: A.R. Johnson has reviewed the commercial performance of the Stone and Webster Residual Oil FCC Unit<sup>3</sup>. This Unit is designed to crack a combination of gas oil and VTB to produce high yields of gasoline. In the review, the heaviest feed processed was a mixture of 31 vol.% VTB in VGO. The blended feed and the VTB has a CCR (wt.%) of 5.5 and 17.7 respectively.

Yen et al of Kellogg presented data correlating coke make with CCR for pilot plant and commercial operations<sup>5</sup>. They studied feedstocks with CCR up to 8.7 wt.%.

J. Bousquet et al evaluating propane, butane and pentane deasphalted oils from light and heavy Arabian vacuum residues, as FCC feedstock<sup>2</sup>. They were able to crack propane and butane DA oils in their pilot plant, but had to blend the pentane DA oil (CCR 11 wt.%) with gas oil.

### 2.3. VTB composition.

Asphaltenes comprise the highest molecular weight material and are classified as the portion of the fluid soluble in benzene but insoluble in a non-polar solvent such as n-pentane or n-heptane.

The deasphalted material is further separated into oils and resins by adsorption (clay) chromatography: the resins contain the remaining polar components while the saturate and aromatic material constitutes the oils. The combined oils and resins fractions are commonly referred to as the maltene fraction, the resins and asphaltenes together are termed asphalt.

The asphaltenes has been studied extensively by many researchers<sup>6-9</sup> and some of the findings are summarized here:

- . Asphaltenes are rich in heteroatoms and deficient in hydrogen. A typical analysis of Athabasca asphaltene is C 79.9, N 1.2, S 7.6, O 3.2 wt.%<sup>6</sup>.
- . Asphaltenes contain the major portion of porphyrins and other organometallic compounds of nickel and vanadium found in crude oil.
- . They contain a fair quantity of stable free radicals<sup>10</sup>.
- . Many Many components in the asphaltene fraction can be separated by column chromatography as acids and bases<sup>8</sup>. Possible basic and acidic functional groups include carboxylic acids, phenols, indoles, amides, pyrazine, sulphoxides, pyridine type structures<sup>7</sup>
- . Recent NMR studies indicate that there are approximately 40 aromatic carbon atoms per 100 carbon atoms in an Athabasca asphaltene<sup>6</sup>. UV studies and thermal techniques<sup>9</sup> suggest the presence of relatively small (1-4 ring) polynuclear aromatic systems rather than large (>10 ring) systems<sup>9</sup>
- . Typical reported average molecular weight of asphaltenes are 2000 to 3600 Daltons<sup>(6,8)</sup>. It has been suggested that the more aromatic structures are relatively low molecular weight (800-1200 Daltons).
- . Asphaltenes strongly associate in solution. In crude oil they are associated with the resins which maintain them in solution.

The resins can be considered as somewhat similar to asphaltenes in that they are polar materials but with lower molecular weight. As such they are generally lower in metals and sulphur and less hydrogen deficient than asphaltenes<sup>1</sup>. They contain a similar range of functional groups to asphaltenes and can be separated into a number of acidic, basic and neutral fractions<sup>11</sup>. According to Nelson<sup>1</sup> resins can be hydrotreated and hydrocracked to yield more valuable products. One aim of the present study is to determine if resins can be catalytically cracked to yield liquid products rather than gas and coque.

### 3. Experimental.

The experimental work carried out in this study included:

- a. Fractionation of Athabasca reduced crude sample.
- b. Characterization of reduced crudes (ATB), the vacuum gas oils and the vacuum tower bottoms samples.
- c. Catalyst characterization.
- d. Deasphalting experiments.
- e. Characterization of DA oils and residues from DA extraction.
- f. Microactivity Testing (MAT) of deasphalted oils and vacuum gas oils.

In Tables 1 and 2 are represented the characterization of feedstocks, as well as the analytical methods employed, where all of them are very well known standard methods. Athabasca VTB is a significantly heavier feedstock than the Lloydminster VTB. It contains approximately one third more sulphur, nitrogen and asphaltic material and two and a half times the Ni+V content. In addition the Conradson Carbon residue for the Athabasca VTB is one third higher than for the Lloydminster sample.

The equilibrium Davison catalyst DA 440 was dried and decoked in accordance with ASTM D3907 prior to characterization. The following properties indicated in Table 3 of the catalyst were determined:

- a. Surface area, pore size distribution and zeolite area by N<sub>2</sub> adsorption-desorption. The BET surface area was determined by ASTM D3663 and the zeolite surface area by Johnson<sup>12</sup> and ASTM D4365.
- b. Surface area, pore volume and pore size distribution by mercury porosimetry, employing a Micromeritics Autopore 9200 porosimeter.
- c. Elemental analysis: V, Ni, Fe, Al by X-ray spectroscopy and Na and Cu by atomic spectroscopy.
- d. Zeolite unit cell dimension by x-ray diffraction according ASTM D3942. The value of 24.42 Å is typical for a REY catalyst.

In addition, microactivity data and physical properties from Davison Chemical.

From the alumina content, the catalyst is designed with an active matrix to encourage bottoms cracking. Based on the porosimetry data, the average matrix pore diameter for the DA-440 catalyst is 280 Å.

The deasphalting experiments include the characterizations of the oils, resins and asphaltenes in the solvent rich and solvent lean phases. The DA oil and the residue are deasphalted using ASTM Method D3279 and the recovered maltene fractions are then separated into oils and resins on an Attapulugus clay column according to GCM

302. For this study, 33 g of clay was used to separate 1 g of maltenes dissolved in 10 ml of n-heptane. The oils were eluted from the column with 200 ml of n-heptane. Resins were then eluted from the column using 70 ml of methylene chloride followed by 70 ml of methylene chloride, 20% diethylether mixture.

As result of the deasphalting studies, the n-butane and n-pentane were the most economically viable solvents in terms of potential quantity and quality of deasphalted oil, so less emphasis was placed on developing comprehensive phase data for the propane and n-heptane systems.

With regard to quality, the presence of asphaltenes and resins in the deasphalted oil reduce its desirability as an FCCU feed, where quality and quantity of a deasphalted oil would appear to be mutually exclusive characteristics in the deasphalting process.

The pressure at any selected deasphalting temperature was set at least 50 psi in excess of the solvent bubble pressure in order to maintain a completely liquid system.

The microactivity tests were carried out following the norm ASTM D-3907-86 and the products analyzed by gas chromatography, simulated distillation with flame ionization detector for liquids and gas chromatography with thermal conductivity detector for gases.

The weight of coke is calculated as:

$$\text{wt.}\% \text{ Coke on catalyst} \times \text{wt. catalyst} \times 1.1 \times 0.01 \quad (1)$$

The 1.1 factor assumes catalytic coke is 91% carbon.

For reasonable quality feedstocks the material balance ranges between 97 and 102%. Under these circumstances, the yields are normalized by adjusting the weight of gas to give a correct material balance. For more asphaltic DA oils the material balance was no longer acceptable because equation 1 overestimates the amount of carbon in additive coke and underestimates the coke yield. In addition to that, the significant coke build-up in the reactor internals which occurs when cracking asphaltic DA oils is not accounted for in the material balance. To solve that problem it was decided to determine the coke make for asphaltic DA oils as the difference in the material balance.

A total of fourteen deasphalted oils prepared from LLOYD VTB, fifteen DA oils prepared from Athabasca VTB and two vacuum gas oils were evaluated. Each oil was cracked at three severities by varying the C/O ratio (2, 4 and 6) while maintaining a reactor temperature at 510°C and a WHSV of 20 h<sup>-1</sup>.

In this study similar results as that from J. Bousquet et al<sup>2</sup> were found. The propane and better quality butane deasphalted oil were relatively easy to test on the microreactor while the another materials were progressively more difficult to test as the CCR increased. For the low CCR oils, the yields were calculated by the standard procedure while for the more asphaltic oils (all the pentane and heptane DA oils plus some butane DA oils) the coke was calculated as the difference in the material balance.

Propane deasphalted oil is normally recognized as good FCC feedstock. The major difference between propane and butane DA oils is the increase in the resin content of the DA oil. This in turn reduces the yield of gasoline and substantially increases the coke yield. With the increased CCR and metals content the butane DA oils could not be considered as a neat charge to an FCC unit but would have to be blended with gas oil.

Pentane and heptane deasphalted oils had high content in resins, where the last ones contained also asphaltenes. For this reason a C/O ratio of 4 were required.

As general relationships between MAT yields and DA Oil quality, with data obtained at a nominal constant severity (C/O ratio of 4) were found three types: Coke correlations, product correlations and metal effects. The sets of data for all Lloydminster and Athabasca DA oils are summarized in Tables 4, 5, 6 and 7.

#### a. Coke correlations.

For these set of data, the most obvious trend is the variation in coke make with both asphalt (resins and asphaltene content) and CCR. Fig. 1 shows the excellent correlation between asphalt content and coke make over the range of 10 to 55 wt.% asphalt.

The concave curvature to the plot suggests that the heavier asphaltic material shows a greater propensity to form coke than the "lighter" resins. In the range to 10 to 25 wt.% resins, the slope of fig. 1 suggests that for every one percent increase in the resin content of the feed above 10%, then there is a corresponding increase in the coke make by 0.4 wt.%, i.e. 40% of the incremental resins are yielded as coke. In the range 48-55 wt.% resins plus asphaltenes, the increased slope suggests that for every one percent increase in the coke make, i.e. all the incremental resins and asphaltenes are yielded as coke.

Fig. 2. shows that there is essentially a straight line relationship between the coke make and feedstock CCR. Moreover, the slope of the line (within the accuracy of measuring the coke)



approximates to a 1:1 relationship between coke make and CCR. These data substantiate the claims of Yen et al<sup>5</sup> that the Conradson Carbon portion of the feed is essentially yielded as coke. Yen plotted CCR ranging from 4 to 8.7 % against coke make ranging from 7.2 to 11.5 %. These data fit the CCR vs. Coke plot for Athabasca and Lloyd DA oils shown in fig. 2. This excellent agreement is somewhat surprising and suggests that the severity of a MAT unit operating at 510 °C and C/O of 4/1 is similar to that of pilot and commercial plant operation.

Operating the MAT unit at a lower C/O of 2 yields less coke while at the higher C/O of 6 more coke is produced. However, for any set of results the difference in coke yield between a 2/1 and a 6/1 C/O ratio is relatively consistent at an average value of 7.3 wt.%. This implies that the coke vs. CCR plots for the various C/O ratios are three parallel lines. To summarize, the CCR is a most important property of DA oil as it sets the additive coke make for the MAT unit.

#### b. Product correlations.

Other general trends noted are a modest increase in dry gas make and a decrease in the C3C4, gasoline, and LCO yields as the asphalt content and CCR of the feed increase. The dry gas make for the two feeds is plotted against the feed asphalt (asphaltene and resins) content in fig. 3, while the three liquid products are plotted against oil content in fig. 4. The dry gas yields are on average higher for the Athabasca DA oils.

As can be seen from fig. 4, there is some discrimination in terms of gasoline production from the two feedstocks, with the Lloydminster on average yielding more gasoline for a given oil content of a feed. Based on the composition of the oils, the Lloyd oil is more crackable than the Athabasca oil, it may have been expected that the difference in gasoline yield would have been more significant. Another source of crackable components are the lighter resins. A correlation between gasoline yield and DA quality was found as follows (see runs 15, 10, 20, 5 and VGO data) :

$$\text{Gasoline yield, wt.\%} = \text{Oil content, wt.\%} \times 0.5 + \text{Resin content, wt.\%} \times 0.165 \quad (2)$$

This simple equation provides a reasonable estimate yield at a C/O ratio of 4/1. At this C/O ratio for DA oils the gasoline yield is normally close to its maximum value, making this a potentially useful method for evaluating DA oils. Obviously other yield, feed quality correlations can be developed using the present data base.

Both the C3C4 and LCO yields show a steady increase as the oil content of the feed decreases. There is little discrimination between the two oils in either set of data.

**c. Metal effects.**

The MAT unit, unlike a commercial FCC unit is not affected by feed metals. Thus, care should be taken to include the deleterious effects of metals, when using this data to relate to potential commercial operation.

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Table 1. Characterization of feedstocks.

Method	Norm	Lloyd VTB	Lloyd VGO	Lloyd ATB
API		6.3	21.1	10.8
Density at 15 °C	ASTM D4052, D1250	1.0262	0.9265	0.9938
Softening point °C	ASTM D36	36	--	--
Pen at 25 °C, 0.1 mm	ASTM D5	192	--	--
Viscosity at 135 °C, Cst	ASTM D2170	205	--	--
Viscosity at 150 °C, Cst	ASTM D2170	113	--	--
Aniline point, °C	ASTM D611	--	65	--
Conradson Carbon, wt. %	ASTM D189	18.34	0.07	--
Total Nitrogen, ppm	ASTM D3228	4964	606	--
Basic Nitrogen, ppm	UOP-269-59	1352	195	--
Total Sulphur, wt. %	ASTM D4294	4.53	2.10	--
Ni, ppm	Zenon/ICP	84	0.10	--
V, ppm	Zenon/ICP	189	0.14	--
Oil fraction, wt. %	GCM 302-3	59.0	--	--
Resin fraction, wt. %	GCM 302-3	27.3	--	--
Asphaltenes, wt. %	ASTM D3279	13.7	--	--
Boiling Range by GCD, °C				
IBP		316	238	232
5%		429	291	337
10%		465	319	370
30%		554	367	460
50%		--	398	554
70%		--	431	--
90%		--	480	--
95%		--	510	--
FBP		--	554	--

Table 2. Characterization of feedstocks.

Method	Norm	Athabasca	Athabasca	Athabasca
		VTB	VGO	ATB
API		-0.7	13.0	6.8
Density at 15 °C	ASTM D4052	1.0818	0.9785	1.0225
Softening point °C	ASTM D36	66	--	--
Pen at 25 °C, 0.1 mm	ASTM D5	11	--	--
Viscosity at 135 °C, Cst	ASTM D2170	2002	--	--
Viscosity at 150 °C, Cst	ASTM D2170	959	--	--
Aniline point, °C	ASTM D611	--	Dark	--
Conradson Carbon, wt. %	ASTM D189	24.33	0.92	--
Total Nitrogen, ppm	ASTM D3228	6390	1635	--
Basic Nitrogen, ppm	UOP-269-59	1820	551	--
Total Sulphur, wt. %	ASTM D4294	5.93	3.73	--
Ni, ppm	Zenon/ICP	130	0.55	--
V, ppm	Zenon/ICP	310	3.50	--
Oil fraction, wt. %	GCM 302-3	46	--	--
Resin fraction, wt. %	GCM 302-3	36.7	--	--
Asphaltenes, wt. %	ASTM D3279	17.3	--	--
Boiling Range by GCD, °C				
IBP		331	313	246
5%		507	364	305
10%		535	379	346
30%		--	417	462
50%		--	448	568
70%		--	475	--
90%		--	515	--
95%		--	544	--
FBP		--	583	--

Table 3. Equilibrium catalyst properties (Davison DA 440).

Method	Value
<u>N<sub>2</sub> adsorption measurements.</u>	
BET surface area, m <sup>2</sup> /g.	75.5
t Plot surface area, m <sup>2</sup> /g	26.7
Zeolite surface area, m <sup>2</sup> /g	48.8
Micropore volume, cc/g	0.025
Zeolite content, wt.%	7.6
<u>Hg intrusion porosimetry to 30Å</u>	
Surface area, m <sup>2</sup> /g	35.0
Intraparticle pore volume, cc/g	0.2453
Average pore diameter, Å	280
<u>Elemental analysis</u>	
V, ppm	141
Ni, ppm	374
Cu, ppm	20
Fe, wt.%	0.72
Na, wt.%	0.34
C, wt.%	0.26
Al <sub>2</sub> O <sub>3</sub> , wt.%	42.1
Unit cell dimension, Å	24.42
<u>Physical properties(Davison)</u>	
Surface area, m <sup>2</sup> /g	76
Pore volume, cc/g	0.26
Apparent Bulk Density, g/cc	0.93
<u>Particle size distribution, wt.%</u>	
0-20μ	1
0-40μ	8
0-80μ	58
APSμ	75
<u>Microactivity data</u>	
% Conversion	70
Coke factor	1.0
Gas factor	1.1

Table 4. Summary of Deasphalting and MAT Results - Lloydminster Data.

Run#	5	23	20	22	32	21	37
MAT#	1	64	4	61	127	15	136
Solvent	C3	C4	C4	C4	C4	C4	C4
Ratio w/w	4.4	7.3	5.1	2.3	0.9	5.1	5.1
Temp., °C	75	120	120	120	120	140	75
Press, psia	465	415	415	415	415	565	205
DAO wt. %	27	60.8	57.5	55.5	25.3	52.7	64.5
Density, g/cc	0.9385	0.9751	0.973	0.9756	1.0069	0.9701	0.978
N, ppm	1120	2012	2080	2030	4238	2047	2623
Basic N, ppm	398	845	876	881	956	1068	735
Con Carbon, wt. %	1.7	5.43	6.1	6.35	12.4	4.57	7.22
Asphaltene	0	0.1	0.1	0.3	5.7	0.2	0.1
Resins	9.8	22.8	21	25.4	32	18.8	24
Oils	90.2	77.1	78.9	74.3	62.3	81	75.9
Ni+V, ppm	2	21	26	31	112	16	27
MAT yields, wt. %							
Gas	4.77	5.73	5.79	6.52	5.88	5.84	5.15
C3+C4	15.58	13.72	14.16	15.5	11.92	14.32	11.92
Gasoline	47.49	43.66	42.53	43.23	41.40	41.65	41.23
LCO	18.27	18.98	19.01	16.66	16.40	18.92	18.73
DO	7.74	8.69	9.31	6.12	6.83	9.81	10.80
Coke	6.15	9.22	9.20	11.97	17.57	9.46	12.17
Conversion	73.99	72.33	71.68	77.23	76.76	71.27	70.46
216 Conv.	67.84	63.11	62.48	65.25	59.2	61.81	58.3
Cat/Oil	3.86	3.93	3.61	4.31	3.91	3.96	4.18

Table 5. Summary of Deasphalting and MAT Results - Lloydminster Data.

Run#	19	24	10	38	14	31	15
MAT#	18	124	73	139	100	121	103
Solvent	C5	C5	C5	C5	C7	C7	C7
Ratio w/w	5.5	1.0	5.5	5.5	11.7	3	8.1
Temp., °C	160	160	140	75	75	75	180
Press, psia	365	365	265	105	65	65	165
DAO wt. %	71.9	91.8	75.1	77	82.7	87.8	87.5
Density, g/cc	0.9876	1.0077	0.9906	0.9939	1.0043	1.0155	1.0065
N, ppm	2680	5304	3136	3395	3101	4846	3456
Basic N, ppm	979	1033	1145	926	1116	1200	1523
Con Carbon, wt. %	9.2	16.6	9.4	10.73	12.8	14.9	13.3
Asphaltene	0.1	9.6	0.2	0.1	1.4	7.5	2.1
Resins	22.6	32.2	32.2	31.2	35.4	30.7	34.4
Oils	77.3	58.2	67.6	68.7	63.2	62.5	63.5
Ni+V, ppm	70	168	80	60	135	126	118
MAT yields, wt. %							
Gas	5.73	6.12	6.33	5.54	6.50	6.06	6.48
C3+C4	11.81	11.45	13.13	11.90	12.57	11.56	13.05
Gasoline	39.22	38.40	39.60	41.49	38.14	36.43	36.12
LCO	17.86	15.25	16.64	17.55	15.87	16.16	15.11
DO	9.56	6.88	7.61	8.12	6.41	8.10	6.94
Coke	15.82	21.90	16.69	15.40	20.51	21.69	22.30
Conversion	72.59	77.87	75.74	74.33	77.71	75.74	77.95
216 Conv.	56.76	55.97	59.06	58.93	57.21	54.05	55.65
Cat/Oil	3.81	4.07	4.09	3.94	3.91	3.90	4.09



Table 6. Summary of Deasphalting and MAT Results - Athabasca Data.

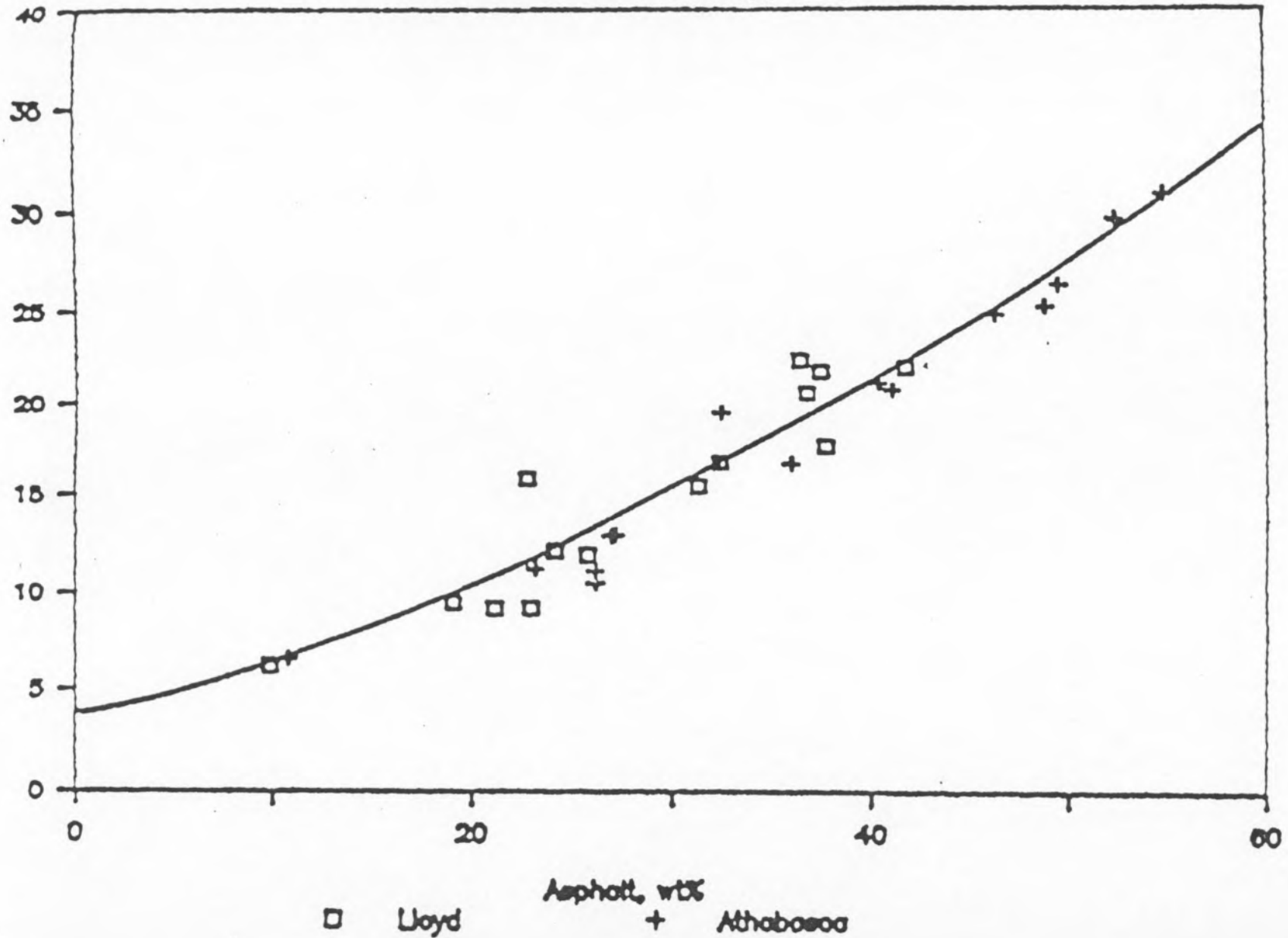
Run#	5	23	20	22	28	21	37
MAT#	10	70	7	67	133	12	142
Solvent	C3	C4	C4	C4	C4	C4	C4
Ratio w/w	4.2	7	4.8	2.1	0.5	4.8	4.6
Temp., °C	75	120	120	120	120	140	75
Press, psia	465	415	415	415	415	565	205
DAO wt. %	12	40.4	39	28.5	94.8	31.5	47.1
Density, g/cc	0.9562	0.9957	0.9937	0.9869	1.0489	0.9897	1.0014
N, ppm	1537	2475	2906	2313	7053	2759	3392
Basic N, ppm	603	1090	1163	1003	1957	1445	1039
Con Carbon, wt. %	2.9	7.22	8.3	6.68	24	6.13	9.37
Asphaltene	0.0	0.0	0.1	0.1	18.5	0.3	0.1
Resins	10.7	27.1	23	26	36.3	25.8	26.8
Oils	89.3	72.9	76.9	73.9	45.2	73.9	73.1
Ni+V, ppm	0.0	32	48	24	370	25	43
MAT yields, wt. %							
Gas	5.58	7.45	6.93	7.28	7.30	6.97	6.30
C3+C4	14.44	13.66	12.48	14.32	9.45	12.54	10.95
Gasoline	45.73	40.05	38.60	41.26	31.66	38.09	37.53
LCO	18.93	17.64	19.39	17.97	14.08	19.34	18.44
DO	8.81	8.26	11.31	8.00	6.58	12.55	13.88
Coke	6.51	12.94	11.29	11.17	30.93	10.51	12.90
Conversion	72.26	74.10	69.30	74.03	79.35	68.11	67.68
216 Conv.	65.75	61.16	58.01	62.86	48.41	57.6	54.78
Cat/Oil	3.89	4.61	3.84	3.98	3.67	3.79	4.07

Table 7. Summary of Deasphalting and MAT Results - Athabasca Data.

Run#	19	24	39	10	38	14	40	15
MAT#	21	130	145	76	148	106	152	109
Solvent	C5	C5	C5	C5	C5	C7	C7	C7
Ratio w/w	5.2	1	6.8	5.2	5	11.1	7.7	7.7
Temp., °C	160	160	160	140	75	75	75	180
Press, psia	365	365	365	265	105	65	65	165
DAO wt. %	58.8	65.3	59.3	59.5	66	80.3	80.5	82.2
Density, g/c	1.0035	1.0736	1.0144	1.018	1.022	1.026	1.0381	1.0359
N, ppm	3615	5198	4639	3459	4284	3500	5771	3036
Basic N, ppm	1451	1523	1092	1222	1264	1570	1401	1664
Con Carbon.	12.8	19.9	12.11	12.4	14.33	18.4	19.4	18.3
Asphaltene	0.2	7.4	0.1	0	0.1	3.3	5.5	2.5
Resins	32.3	38.9	35.9	41.1	40.3	46.2	43.3	49.9
Oils	67.5	53.7	64	58.9	59.6	50.5	51.2	47.6
Ni+V, ppm	154	322	77	111	140	253	195	248
MAT yields, wt. %								
Gas	6.81	7.28	6.94	7.72	7.54	7.60	7.29	8.56
C3+C4	9.92	10.67	10.92	12.02	12.73	11.18	10.43	12.44
Gasoline	35.52	36.22	37.92	36.83	36.34	32.78	34.19	30.59
LCO	17.87	14.82	16.94	15.70	15.78	14.74	15.59	12.91
DO	10.46	6.25	10.65	7.04	6.53	7.32	7.28	5.82
Coke	19.42	24.76	16.63	20.69	21.08	26.38	25.22	29.68
Conversion	71.67	78.93	72.41	77.26	77.70	77.93	77.12	81.27
216 Conv.	52.25	54.17	55.78	56.57	56.61	51.56	51.91	51.59
Cat/Oil	3.82	4.34	4.34	4.33	4.64	4.40	4.52	4.66

Figure 1.

Coke Make vs DAO Asphalt (C/O-4)



Coke, wt%

Figure 2.

Coke Moles vs DAG CCR (O/O-4)

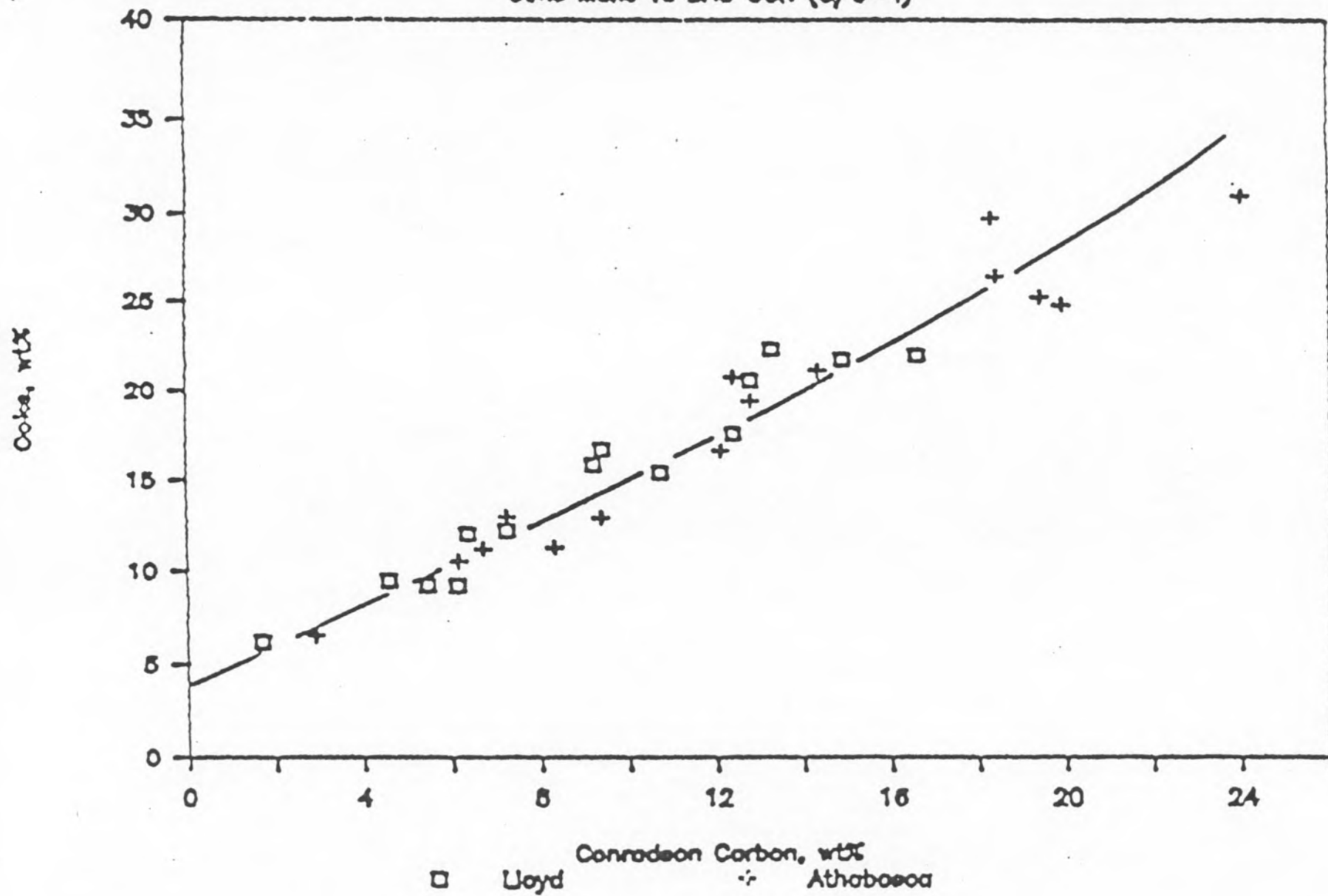


Figure 3.

Dry Gas Moles vs DAO Asphalt (C/O-4)

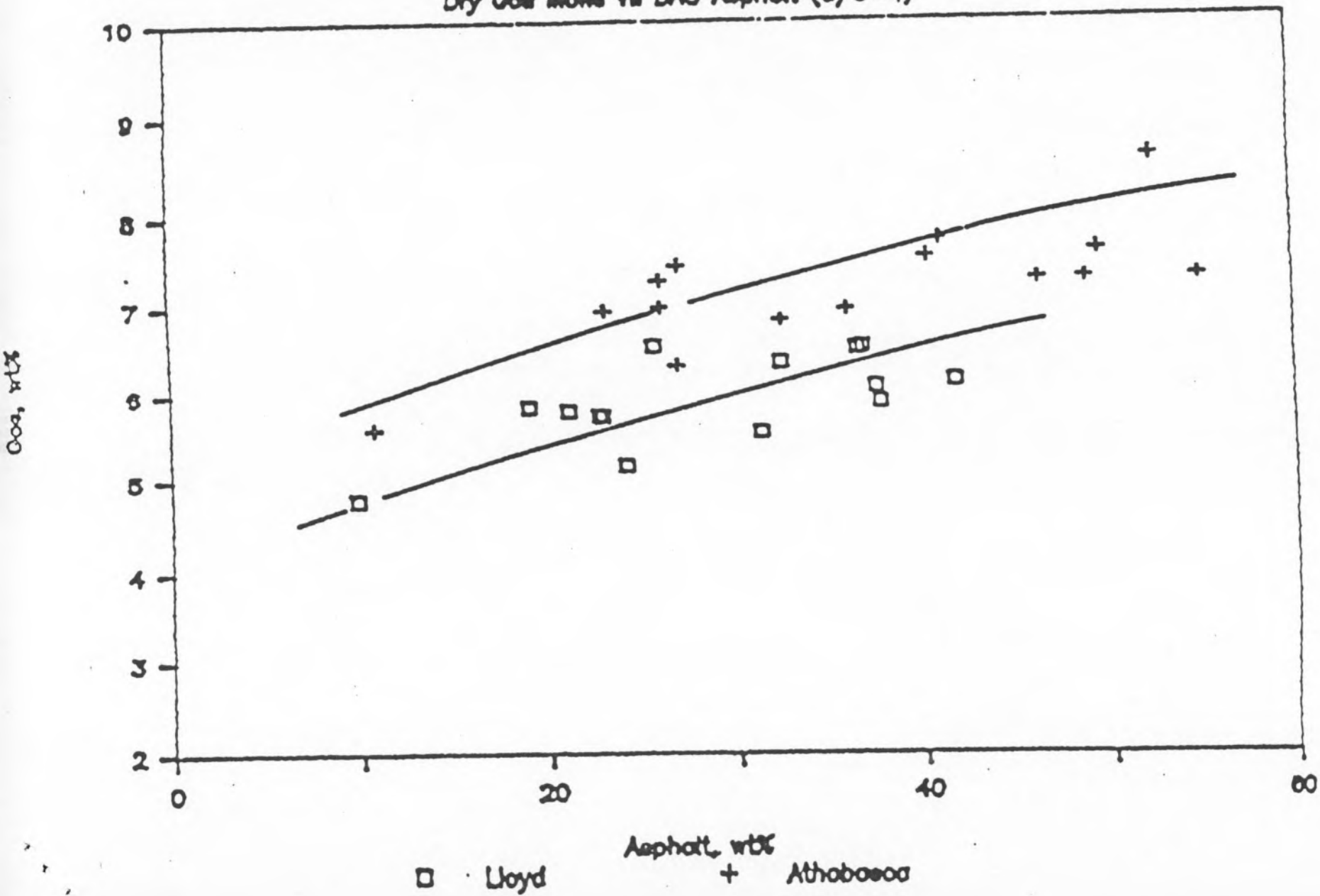


Figure 4.

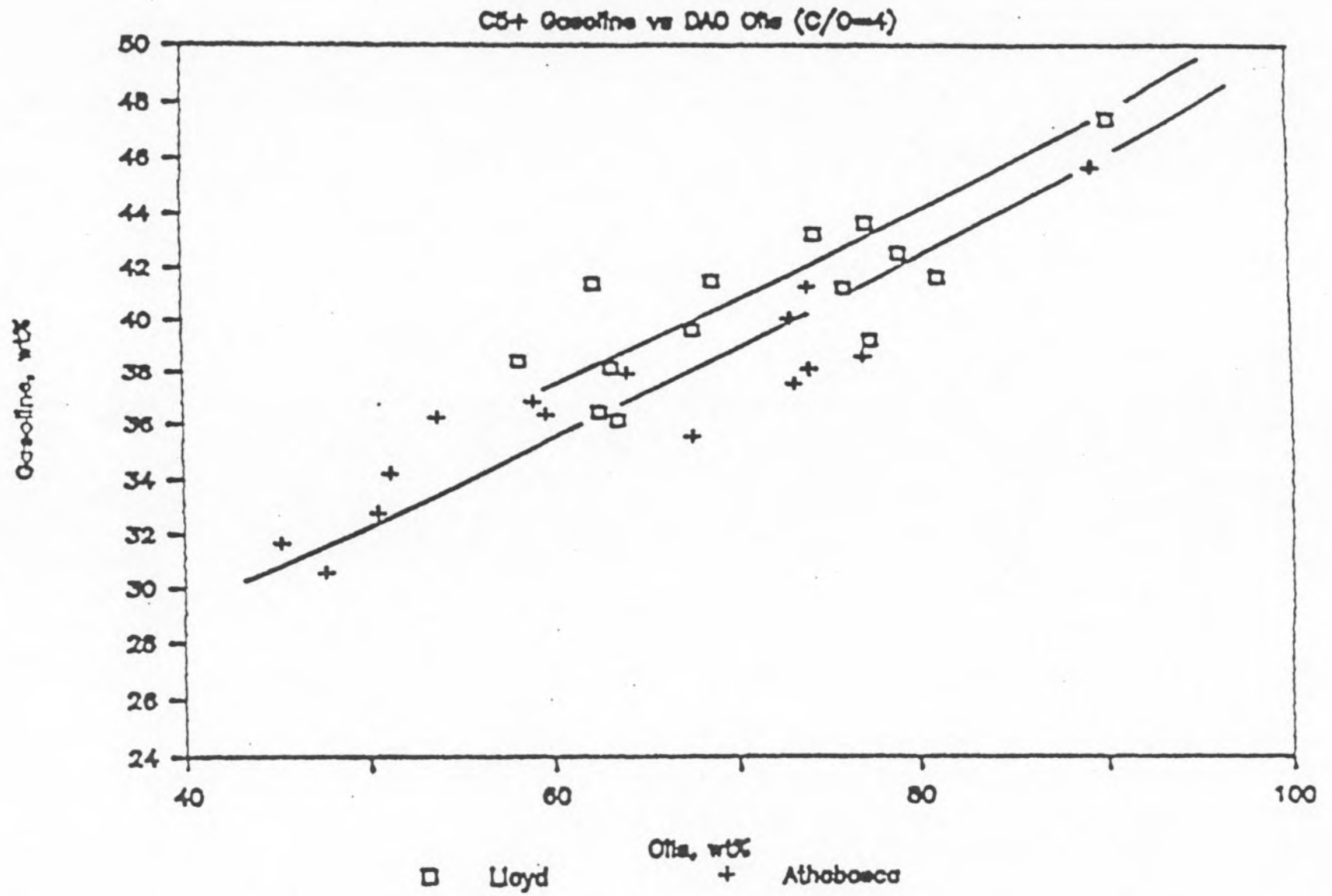


Figure 5.

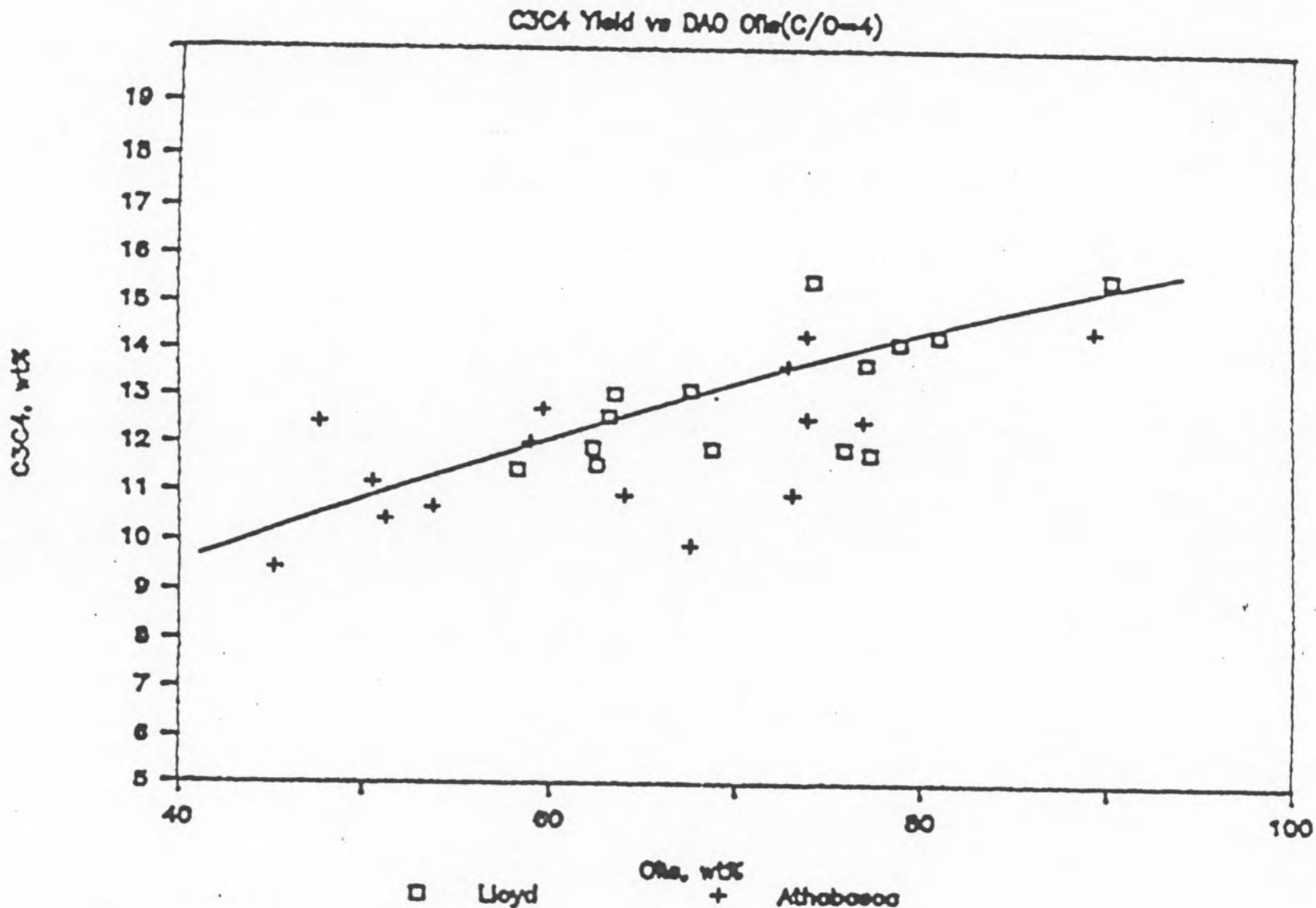


Figure 6.

