FLUID CHARACTERIZATION

Title TBP-DISTILLATION, WAX, HYDROCARBON ANALYSIS OF CRUDE OIL FROM WELL 15/9-19A DST 2B VOLVE
Prepared by **NORSK LAB**
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Title
TBP-DISTILLATION, WAX, HYDROCARBON ANALYSIS OF CRUDE OIL FROM WELL 15/9-19A DST 2B (VOLVE)

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Abstract

All analyses were performed on separator oil received in a pressurized 20 l Xample bottle.

Key analytical data of crude oil from:	15/9-19A DST 2B
Molecular weight:	256 g/mole
Density at 15 °C:	891 kg/m^3
Weight % C_{10+}:	86,75 wt%
Wax content wt %:	17,4 / 4,9 (total / purified):
Pentane insolubles:	4,86 wt% (precipitated 1x)
Sulphur content:	2,03 wt%
Pour point, min.:	-30 °C
Wax precip. temp.:	32,7 °C

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INTRODUCTION

The results from a True Boiling Point (TBP) distillation and chemical and physical characterization of crude oil from well 15/9-19A DST 2B are presented in this report.

All analyses were performed on crude oil from test separator received in a pressurized 20 l bottle. The bottle was preheated to 60 °C (separator temperature) to dissolve any precipitated wax before single flash to ambient conditions.

TBP-distillation including detailed composition of C_5-C_9 fraction was performed by Core Laboratories, Aberdeen. The distillation was performed by a combination of atmospheric and vacuum distillation up to C_{20+}. Molecular weights and densities of fractions from C_{10} to C_{19} were determined by physical methods, whereas those below C_{10} were calculated from properties of the individual components and composition from gas chromatography.

The GC-MS analyses to determine group type distribution in carbon number fraction C_{10}-C_{19} were performed by SINTEF Kjemi, Oslo.

The simulated distillation by high temperature gas chromatography was performed by PKS, Statoil-Mongstad.

The following analyses were performed by West Lab ASA:

- Minimum and maximum pour point
- Wax precipitation temperature / Wax dissolution temperature
- Total wax content
- Saturate - aromatic - polar distribution in C_{10+} and C_{20+} residues
- Content of pentane insoluble asphaltenes
- Water content
- Sulphur content
- Acid number and nitrogen bases
- Emulsion stability test

Analyses performed by Statoil, F&U:

- Kinematic viscosity from 80 °C to 40 °C
- Apparent viscosity at various shear rates from 40 °C to 0 °C

Some data of the sample used, are summarized in Table 1 below and a summary of essential analytical data is given in Table 2. A gas chromatogram of the oil is shown in Figure 4.

Table 1. Data of sample used in this investigation

Well	15/9-19A VOLVE
Test no.	DST 2B, Main flow
Field	Sleipner, Volve
Formation	Hugin
Perforation / Sample depth m TVD MSL	3079,9 –3077,5 3021,2 – 3056,3
Fluid type	Crude oil
Sampling point	MTU oil outlet
Bottle no.	50257 Xample
Date of sampling	31/10/97
Time of sampling	04:57 – 05:07
Separator pressure	13,0 bara
Separator temperature	59,2 deg C

Table 2. Summary of key analytical data of crudeoil 15/9-19A DST 2B

		Crude oil	C_{10+} fraction	C_{20+} fraction
Weight % of crude oil		100	86,75	60,03
Molecular weight (g/mole)		256 (a)	346	570
Density (g/cc)		0,891	0,927	0,973
Water content (wt%)		0,05		
Sulphur content (wt%)		2,03		
Wax content (wt%)	Not purified	17,4		
	Purified	4,9		
Pentane insolubles (wt%)	Precipitated 1 X	4,86		
	Precipitated 2 X	3,77		
Saturates (wt%)			34,9	27,6
Aromatics (wt%)			52,9	57,0
Polars (wt%)			7,8	9,1
Total acid number (mg KOH/g)		0,07		
Nitrogen bases (wt%)		0,08		
Pristane/Phytane (b)			0,686	
Pristane /n-C_{17} (b)			0,805	
Phytane /n-C_{18} (b)			1,32	
n-C_{17}/n-C_{27} (b)			3,95	
Pour point (°C)	Minimum (c)	- 30		
	Temp.cycled (d)	- 10		
	"As received" (e)	- 4		
Wax precipitation temperature (°C)		32,7		
Wax dissolution temperature (°C)		43		
Kinematic viscosity (cSt)	80 °C	7,9		
	70 °C	9,1		
	60 °C	13,2		
	50 °C	17,1		
	40 °C	23,6		

(a) Average of calculated molecular weights using C_{10+} and C_{20+}
(b) Area percent ratio from paraffin-naphthene chromatogram
(c) After preheating to 80 °C (thermal benefication)
(d) Reheated from minimum pour point to 50 °C and then recooled
(e) Without thermal benefication

RESULTS

Table 2 gives a summary of key analytical data. The crude oil from well 15/9-19A DST 2B is a relatively heavy oil, with a high content of asphalthenes (4,9 wt%) and sulphur (2,03 wt %). The aromatic fraction is also quite high (52,9 wt%). The acid number is quite low. The acid number is relatively low. Most crude oils from the North Sea have acid number in the range 0,05 – 0,2 mg KOH/g. The acid number indicates the content of organic acids in the oil, primarily of high molecular weight since low MW acids are likely to enter the water phase in the reservoir.The crude oil has very low pour point which correspond with the low wax appearance point (WAT).

Table 3 gives the boiling point distribution of the oil on weight, volume and mole basis as well as densities and molecular weights of each distillation fraction. The volumetric boiling point distribution to C_{20+} is illustrated in **Figure 1**.

Table 4 compares molecular weights and densities of crude oil and residues obtained by direct measurements with values obtained by summation of individual fractions. The observed discrepancy between measured and calculated molecular weights is within normal experimental uncertainty. The average of the **calculated** molecular weights is believed to be the most reliable.

Table 5 gives the overlap between successive distillation fractions as determined by capillary gas chromatography.

Table 6 gives the detailed composition of the light end of the crude oil, including n-C_9. The weight percent of individual compounds and pseudocomponents from gas chromatography were normalised to fit the experimental C_{10+} weight percent from distillation.

Table 7 gives the complete boiling point distribution of the crude oil obtained by combining the GC-analysis of the light end with the distillation to C_{20+} and simulated distillation of the C_{20+} residue to C_{100+} high temperature gas chromatography (HTGC) with internal standard.The atmospheric equivalent boiling point corresponding to n-C_{100} is 725 °C. The boiling point distribution on weight basis is illustrated in **Figure 2**. The high temperature gas chromatogram is shown in **Figure 8**.

Table 8 gives the distribution of saturates (paraffins + naphthenes) and aromatics in all distillation fractions calculated according to a correlation between aromatic content and density of the fractions (**ref. 3**). Check against experimental values of the C_{14} and C_{19} fraction show discrepancy out of normal error (2 wt%) for the correlation. All fractions from C_{14} to C_{19} where therefore checked experimentally. For the C_{10+} and C_{20+} residues the amount of polars were estimated using an "in-house" correlation between weight fractions of polars and aromatics in C_{10+}(**ref. 4**).

Table 9 gives the detailed hydrocarbon group type distributions of fractions C_{10} to C_{19} as determined by gas chromatography - mass spectrometry.

Table 10 gives some component ratios between compounds < n-C_9, known as Thompson's Indices (**ref. 2**) which give aromatic hydrocarbons relative to normal alkanes of similar molecular weight, and unbranched alkanes and naphthenes relative to branched isomers and paraffins relative to naphthenes. The component ratios provide information about maturity, migration and fractionation of the petroleum fluid in the reservoir, and are useful for comparison of crude oils.

Table 11 gives some characteristic ratios between individual compounds > n-C_{10} , primarily of geochemical interest, based upon area percents from FID gas chromatograms of the saturate and aromatic subfractions (**Figures 5, 6 and 7**).

Table 12 gives the viscosity data of the crude oil in the temperature range 0-80 °C. For temperatures of 40 °C and higher, the dynamic viscosities were calculated from kinematic viscosities using densities in Table 13.
Below 35 °C the apparent (shear dependent) viscosity of thermally beneficated oil is reported at four different shear rates.These viscosities were obtained by cooling the oil at a rate of 12.5 °C/hour and the specified rate in the viscosimeter.
The viscosities at shear rate 30 s-1 are relatively high compared to the data at the shear rates 100, 300 and 500 s-1. The reason is not known, but could be related to problems with shear rate control at low shear rates. The viscosities at 30 s-1 are thus not considered reliable.
The oil is seen to be more or less Newtonian at temperatures down to about 15 °C. The viscosity-temperature relationship is shown as a graph in Figure 3.

Table 13 summarizes the kinematic viscosities in the Newtonian temperature range as measured with a Ubbelohde glass capillary viscometer tube and the densities used to convert the kinematic viscosities to the dynamic viscosities in Table 12.

Table 14. The result of bottle tests at 50°C with synthetic water-in-oil emulsion , 20% and 50% water cut, are summarized in Table 14.1 (untreated) and 14.2 (treated with 10 ppm demulsifier, SOC-6011X.). Emulsions were prepared with fresh separator oil immediately after flash to atmospheric conditions. Oxidation due to air was then minimized. The test indicated that the untreated 15/9-19A DST 2B crude oil forms stable emulsions at 50°C. With 10 ppm, 60% and 100% free water break-out was achieved within 15 minutes for the 20% and 50% emulsion respectively. The water separation curves are presented in **Figure 9**. The synthetic formation water used in the emulsion tests is based on composition of real formation water. The composition of the formation water is given in Appendix B.

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Table 3. Data from TBP distillation of stabilized crude oil 15/9-19 DST 2B

Cut	Temp deg C	Wt%	Cum Wt%	Density	Vol%	Cum Vol%	Mol Wt	Mole %	Cum Mol %
C_{4-}		0.76	0.76	0.56	1.21	1.21	53.9	3.58	3.58
C_5		1.14	1.90	0.628	1.62	2.83	72.15	4.03	7.61
C_6	69.2	1.43	3.33	0.669	1.91	4.74	84.69	4.30	11.91
C_7	98.9	3.08	6.41	0.743	3.70	8.44	91.41	8.58	20.49
C_8	126.1	3.58	9.99	0.764	4.19	12.63	104.95	8.70	29.19
C_9	151.3	3.26	13.25	0.775	3.76	16.39	118.82	7.00	36.19
C_{10+}	>151.3	86.75	100.00	0.927	83.61	100.00	346	63.81	100.00
C_{10}	174.6	2.72	15.97	0.7826	3.08	19.47	131.4	5.26	41.45
C_{11}	196.4	2.64	18.61	0.7962	2.95	22.42	146.2	4.61	46.06
C_{12}	216.8	2.55	21.16	0.8109	2.80	25.22	159.7	4.07	50.13
C_{13}	235.9	2.54	23.70	0.8229	2.74	27.96	173.4	3.73	53.86
C_{14}	253.9	2.62	26.32	0.8324	2.80	30.76	185.6	3.59	57.45
C_{15}	271	3.19	29.51	0.8498	3.33	34.09	198.5	4.09	61.54
C_{16}	287.3	2.79	32.30	0.8511	2.92	37.01	218.5	3.26	64.80
C_{17}	303	2.96	35.26	0.8531	3.08	40.09	235.7	3.20	68.00
C_{18}	317	2.56	37.82	0.8631	2.63	42.72	249.4	2.61	70.61
C_{19}	331	2.15	39.97	0.878	2.17	44.89	260.2	2.10	72.71
C_{20+}	>331.0	60.03	100.00	0.9733	54.82	99.71	570	26.58	99.29

Table 4. Measured and calculated molecular weights and densities of crude oil 15/9-19A DST 2B

	Whole Oil	C_{10+} Fraction	C_{20+} Fraction
Measured MW	257	346	570
Calculated MW using C_{10+} MW	255	-	-
Calculated MW using C_{20+} MW	256	349	-
Measured density	0,891	0,927	0,973
Calculated density using C_{10+} density	0,893	-	-
Calculated density using C_{20+} density	0,892	0,925	-

Table 5. Weight distribution and weight% overlap between fractions of crude oil 15/9-19A DST 2B

Fraction	Weight %	C_{n-1} Rel %	C_n Rel %	C_{n+1} Rel %
C_{4-}	0,76	-	-	-
C_5	1,14	-	-	-
C_6	1,43	0	100	0
C_7	3,08	0	100	0
C_8	3,58	0	100	0
C_9	3,26	0	100	0
C_{10}	2,72	0	100	0
C_{11}	2,64	17	64	19
C_{12}	2,55	18	60	22
C_{13}	2,54	17	60	23
C_{14}	2,62	21	55	24
C_{15}	3,19	19	52	29
C_{16}	2,79	21	41	38
C_{17}	2,96	30	30	40
C_{18}	2,56	27	28	45
C_{19}	2,15	28	34	38

Table 6. Composition of stabilized crude oil 15/9-19A DST 2B (gas chromatography)

Component G_p	Weight %	Molecular Weight	Density
C_1	0,00	16,0	0,260
C_2	0,01	30,1	0,350
C_3	0,16	44,1	0,508
iC_4	0,09	58,1	0,563
nC_4	0,50	58,1	0,585
2,2-DM-C_3	0,00	72,2	0,597
iC_5	0,41	72,2	0,625
nC_5	0,73	72,2	0,631
Hexanes Total	1,43	84,7	0,669
Hexanes - P	1,32	86,2	0,663
Hexanes - N	0,11	70,1	0,750
Heptanes Total	3,08	91,4	0,743
Heptanes - P	1,32	100,2	0,688
Heptanes - N	1,28	89,0	0,761
Heptanes - A	0,48	78,1	0,884
Octanes Total	3,58	105,0	0,764
Octanes - P	1,40	114,2	0,707
Octanes - N	1,37	104,9	0,771
Octanes - A	0,81	92,1	0,871
Nonanes Total	3,26	118,8	0,775
Nonanes - P	1,57	128,3	0,721
Nonanes - N	0,78	117,7	0,791
Nonanes - A	0,91	106,2	0,870
Decanes Plus	86,75	346,0	0,927

Table 7. Simulated distillation by high-temperature GC-analysis of the C_{20+} fraction of crude oil 15/9-19A DST 2B

Fraction	% of crude oil (w/w)	% cumulative (w/w)	Boiling point (°C)
Gas	0,76	0,76	
C_5	1,14	1,90	36,5
C_6	1,43	3,33	69,2
C_7	3,08	6,41	98,9
C_8	3,58	9,99	126,1
C_9	3,26	13,25	151,3
C_{10}	2,73	15,98	174,6
C_{11}	2,64	18,62	196,4
C_{12}	2,55	21,17	217,2
C_{13}	2,54	23,71	235,9
C_{14}	2,62	26,33	253,9
C_{15}	3,19	29,52	271,1
C_{16}	2,79	32,31	287,3
C_{17}	2,96	35,27	303,0
C_{18}	2,56	37,83	317,0
C_{19}	2,15	39,98	331,0
C_{20}	0,93	40,91	344
C_{21}	1,64	42,56	357
C_{22}	1,75	44,31	369
C_{23}	2,01	46,32	381
C_{24}	1,58	47,90	391
C_{25}	1,67	49,58	402
C_{26}	1,58	51,16	412
C_{27}	1,09	52,25	423
C_{28}	0,77	53,02	431
C_{29}	2,87	55,89	441
C_{30}	2,18	58,07	449
C_{31}	1,51	59,58	457
C_{32}	1,55	61,13	466
C_{33}	1,40	62,53	474
C_{34}	1,25	63,78	481
C_{35}	1,37	65,15	489
C_{36}	1,15	66,30	496
C_{37}	1,08	67,38	502
C_{38}	1,25	68,62	509
C_{39}	1,17	69,79	516
C_{40}	1,02	70,81	522
C_{41-45}	4,94	75,75	551
C_{46-50}	3,77	79,53	575
C_{51-55}	3,08	82,60	596
C_{56-60}	2,61	85,21	615
C_{61-65}	2,17	87,38	632
C_{66-71}	1,83	89,21	647
C_{71-75}	1,67	90,88	661
C_{76-80}	1,45	92,34	675
C_{81-85}	1,23	93,57	688
C_{86-90}	1,22	94,79	700
C_{91-95}	1,02	95,81	710
C_{96-100}	0,86	96,68	720
C_{100+}	3,32	100,00	720+

Table 8. Hydrocarbon group type distribution (w/w) in distillation fractions and residues of crude oil 15/9-19A DST 2B

C_n	Paraffins + naphthenes	Aromatics	Polars	Asphaltenes
6 a	100,0	0,0		
7 a	84,4	15,6		
8 a	77,3	22,6		
9 a	72,1	27,9		
10 c	84,9	15,1		
11 c	79,9	20,1		
12 c	80,2	19,8		
13 c	79,1	20,9		
14 b	74,6	25,4		
15 b	66,3	33,7		
16 b	66,8	33,2		
17 b	66,4	33,6		
18 b	65,5	37,5		
19 b	57,4	42,6		
20+ b	27,6	57,0	9,1	6,3
10+ b	34,9	52,9	7,8	4,4

(a) From GC-analysis
(b) Experimental values (preparative liquid chromatography)
(c) Calculated using correlations between density and aromatic content (ref.3)

Table 9. PNA-distribution of distillation fractions C_{10} - C_{19} of crude oil 15/9-19A DST 2B from GC-MS

Unit : WEIGHT %

Compound	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}
Paraffins	40,4	40,8	37,7	37,5	37,9
Naphthenes	35,4	34,3	32,4	30,7	29,7
Alkylbenzenes	24,1	21,1	18,3	13,5	10,8
Indanes + Tetralines	0,10	2,89	8,65	12,9	13,5
Naphthalene	0,00	0,89	2,32	0,66	0,13
Alkylnaphthalenes	0,00	0,00	0,64	4,55	6,56
Acenaphthenes + Biphenyles	0,00	0,00	0,00	0,15	1,51
Fluorenes + Acenaphthylenes	0,00	0,00	0,00	0,00	0,00
Phenanthrenes	0,00	0,00	0,00	0,00	0,00
Dibenzothiophenes	0,00	0,00	0,00	0,00	0,00
Compound	**C_{15}**	**C_{16}**	**C_{17}**	**C_{18}**	**C_{19}**
Paraffins	34,7	38,3	40,6	38,1	32,5
Naphthenes	31,0	30,2	28,9	31,0	32,9
Alkylbenzenes	9,49	8,62	7,28	4,92	2,05
Indanes + Tetralines	12,4	7,49	4,02	1,72	0,41
Naphthalene	0,00	0,00	0,00	0,00	0,00
Alkylnaphthalenes	8,75	7,57	6,09	4,61	2,72
Acenaphthenes + Biphenyles	3,42	6,70	10,6	14,38	16,1
Fluorenes + Acenaphthylenes	0,25	0,87	1,30	2,08	7,69
Phenanthrenes	0,00	0,06	0,40	1,00	1,73
Dibenzothiophenes	0,00	0,16	0,79	2,09	3,94

Table 10. Thompson's Indices of stabilized crude oil 15/9-19A DST 2B

Index	Value
A	0,658
B	1,03
X	0,493
C	1,81
I'	0,683
F	1,46
H	30,04
U	0,612
R'	2,82
W	1,60

Definition of Thompson's Indices symbols

A: Benzene / n-hexane
B: Toluene / n-heptane
X: meta+para-xylene / n-octane
C: $n\text{-}C_6 + n\text{-}C_7$ / ($cy\text{-}C_6$ + methyl-cy-C_6)
I': 3-methyl-C_6 / (1-ci,3+1-tr,3+1-tr,2)dimethyl-cy-C_5
F: n-heptane / methyl-cy-hexane
H: 100*$n\text{-}C_7$ / ("heptanes" - methyl-cy-C_5 - 2,4-di-methyl-C_5 - Benzene + methyl-cy-C_6)
U: $cy\text{-}C_6$ / methyl-cy-C_5
R': $n\text{-}C_7$ / 3-methyl-C_6
W: Benzene / $cy\text{-}C_6$

Table 11. Characteristics ratios of some individual saturated and aromatic compounds in crude oil 15/9-19A DST 2B

Saturated compounds

	Area percent ratio
Pristane/phytane	0,686
Pristane/n-C_{17}	0,805
Phytane/n-C_{18}	1,32
n-C_{17}/n-C_{27}	3,95
CPI 1 *	1,00
CPI 2 *	0,855

Aromatic compounds

	Area percent ratio
2MN/1MN	1,02
2.6+2.7-/1.4+1.5+2.3 DMN	0,964
Biphenyl/1+2 EN	0,479
Biphenyl/3M-biphenyl	0,178
MPI 1 *	1,27
MPI 2 *	1,07

N = naphtalene
M = methyl-
DM = dimethyl-

* See definition of CPI and MPI in Appendix D.

Table 12. Viscosity[a] of crude oil 15/9-19A DST 2B

Temp. (°C)	Dynamic viscosity[b] (mPa s)			
80°	6,71			
70°	7,80			
60°	11,4			
50°	14,9			
40°	20,7			
	Viscosity[c] (mPa s) at shear rate			
	30 s^{-1}	100 s^{-1}	300 s^{-1}	500 s^{-1}
34°	36,7	22,8	23,3	22,6
32°	40,5	24,9	25,3	24,5
30°	47,1	27,5	26,5	25,8
28°	52,5	30,3	30,6	29,8
26°	58,3	33,3	33,9	33,2
24°	66,2	37,1	37,4	36,5
22°	73,9	38,8	41,8	40,4
20°	78,5	43,0	46,7	45,8
18°	84,8	48,9	52,5	50,9
16°	109	59,9	60,4	57,6
14°	126	69,8	69,4	65,3
12°	145	83,9	80,7	74,6
10°	171	103	93,1	85,8
8°	197	129	109	98,1
6°	234	165	129	113
4°	279	217	152	130
2°	331	285	179	154
0°	391	360	209	181

[a] *Performed by Statoil F&U*
[b] *Calculated from kinematic viscosities and densities in Table 13*
[c] *Viscosimeter cooled at a rate of 12,6 °C/hour from 34 °C to 2 °C at various constant shear rates*

Table 13. Kinematic viscosity and density of crude oil 15/9-19A DST 2B at various temperatures

Temperature	Kinematic viscosity[a] (cSt)	Density[b] (kg/m^3)
80°	7,9	849,9
70°	9,1	856,9
60°	13,2	863,9
50°	17,1	870,9
40°	23,6	877,8

[a] *Performed by Statoil F &U*

[b] *Measured at 15 °C (895.9 kg/m^3) Calculated at other temperatures using API standard 2540 (august 1980).*

Table 14.1 Water separation from synthetic water-in-oil emulsions with crude oil 15/9-19A DST 2B at 50 °C. No emulsion breaker

Water cut (%)	% of original water separated as free water after						
	1 min	3 min	6 min	10 min	15 min	20 min	30 min
20	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0

Table 14.2 Water separation from synthetic water-in-oil emulsions with crude oil 15/9-19A DST 2B at 50 °C. 10 ppm emulsion breaker #

Water cut (%)	% of original water separated as free water after						
	1 min	3 min	6 min	10 min	15 min	20 min	30 min
20	0	0	5	25	60	70	80
50	2	3	3	34	100	100	100

SOC-6011X (TROS); 10 ppm (vol/vol) based on total volume of oil and water.

Figures

Figure 1: TPB- AND DENSITY PROFILES, CRUDE OIL 15/9-19A DST 2B

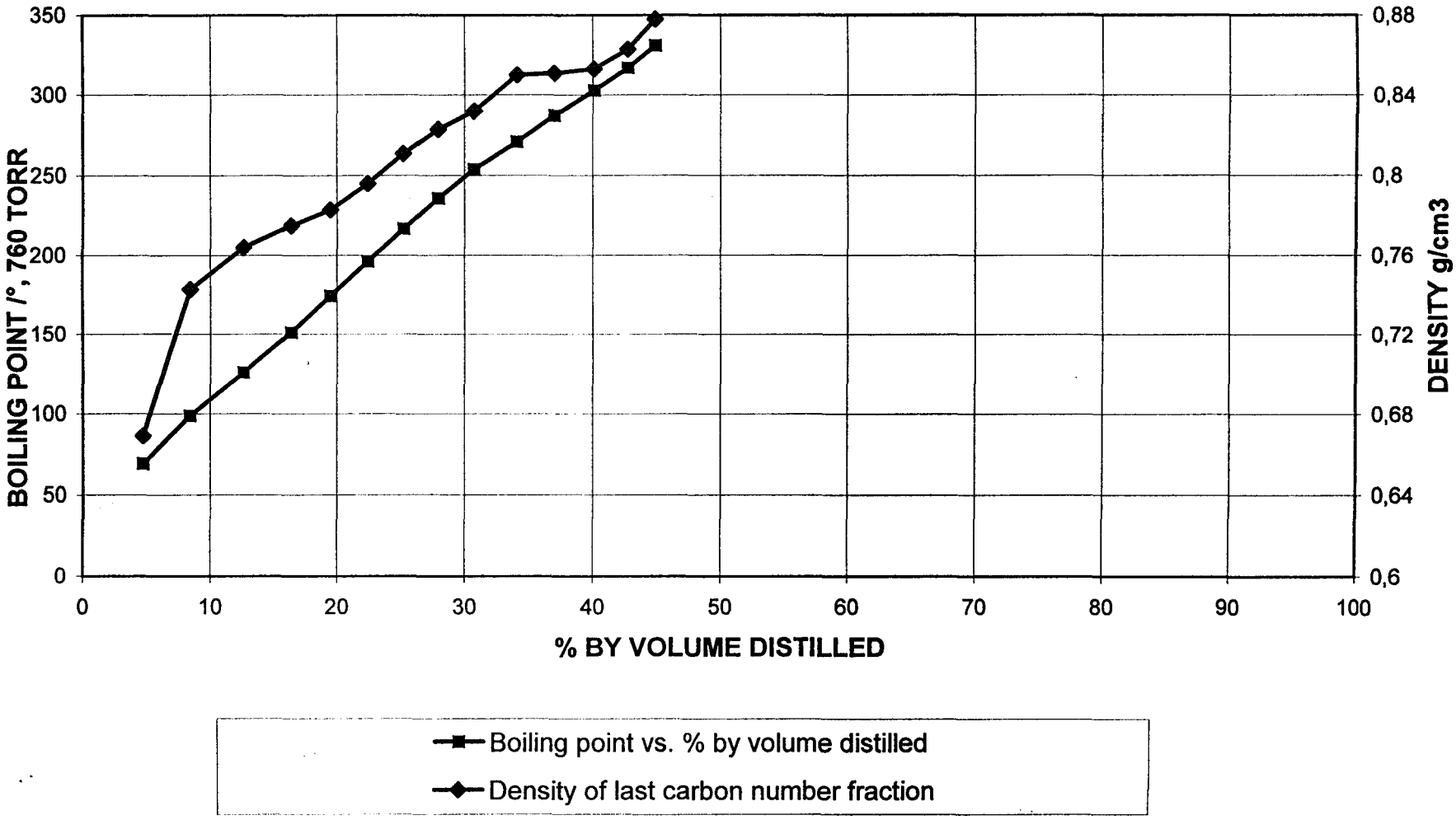

Figure 2: Boiling point distribution to C_{100+} for crude oil 15/9-19A DST 2B

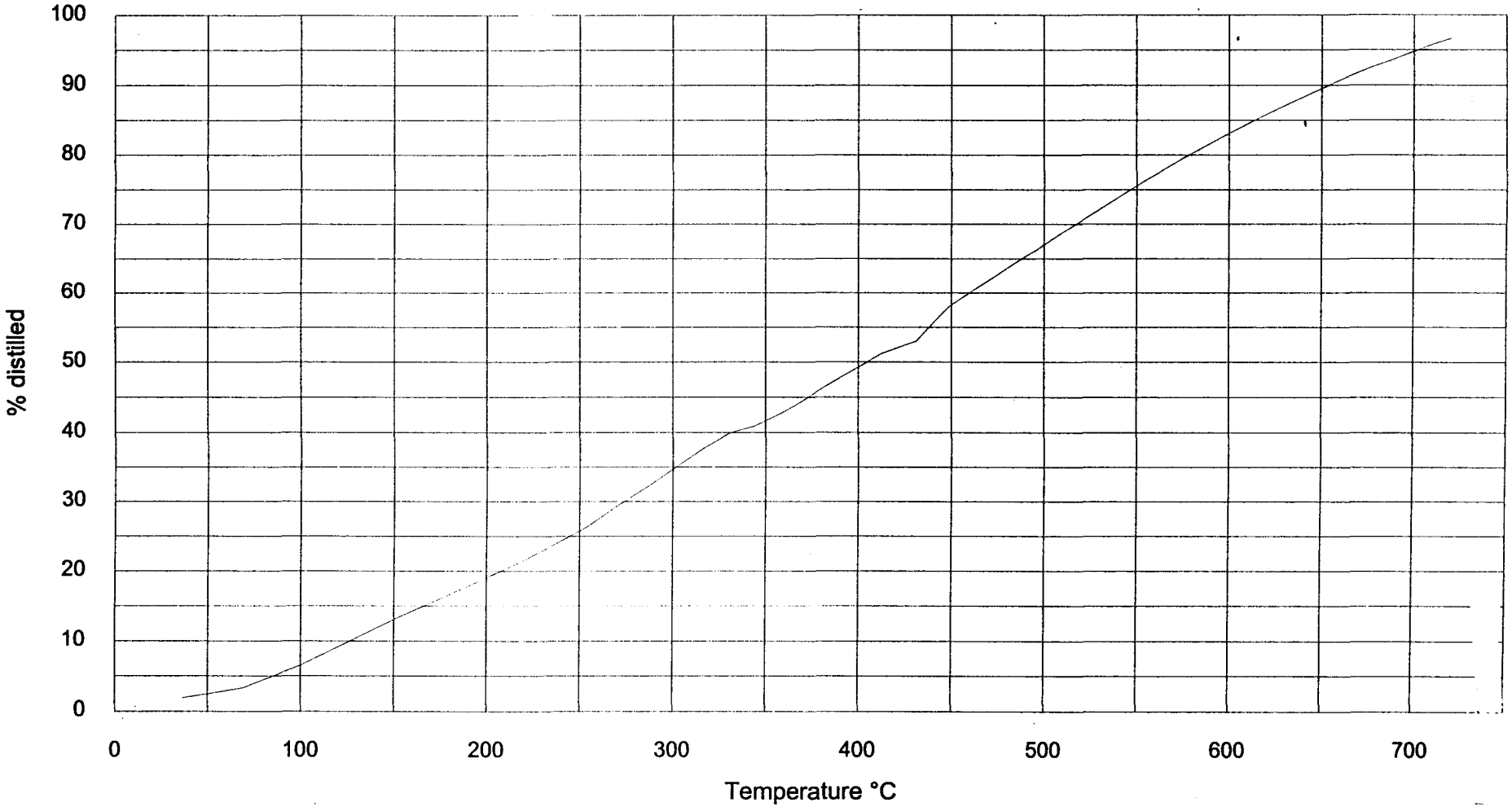

FIG.3 15/9-19A DST 2B

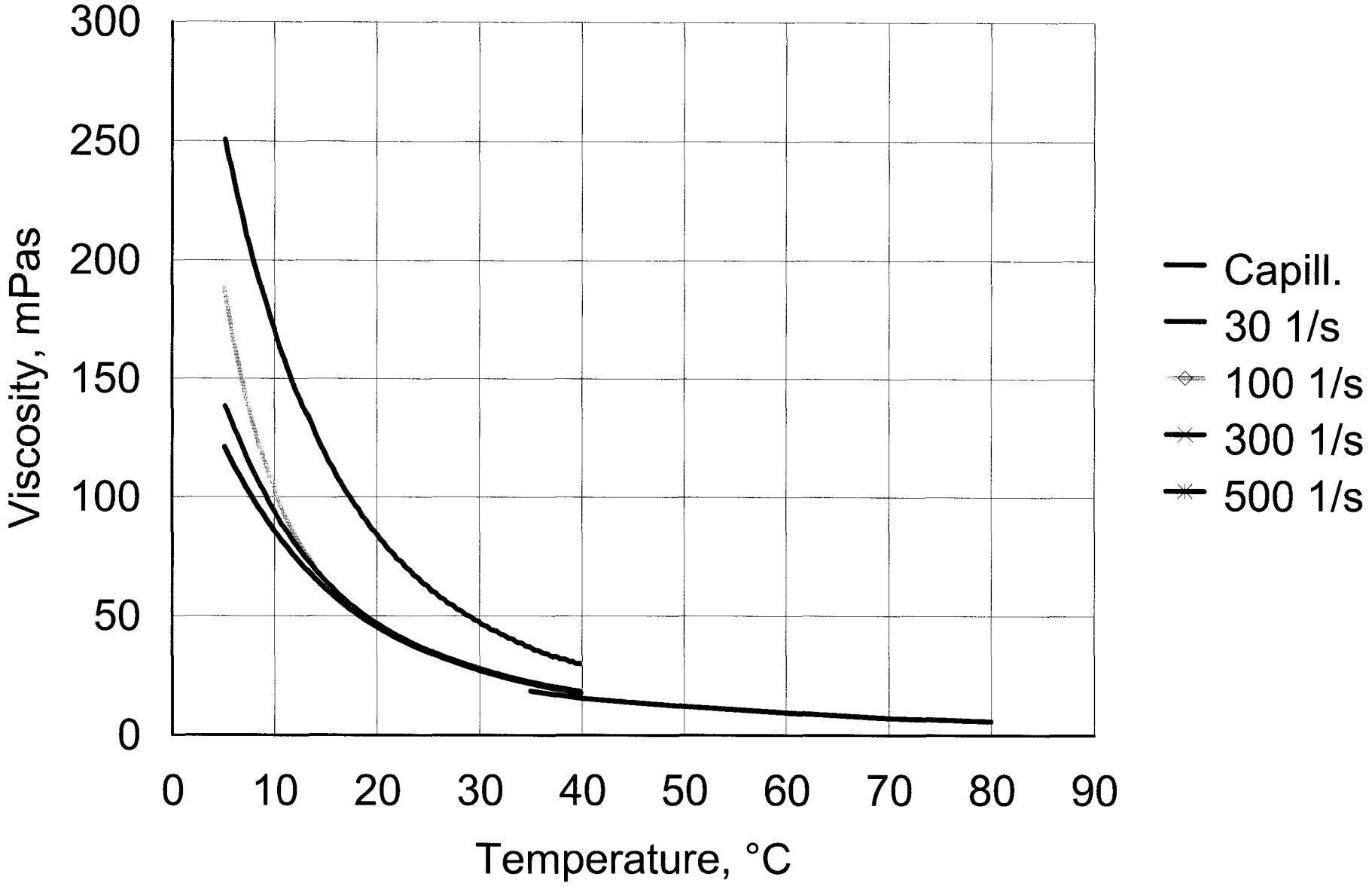

Figure 4: CRUDE OIL 15/9-19A DST 2B

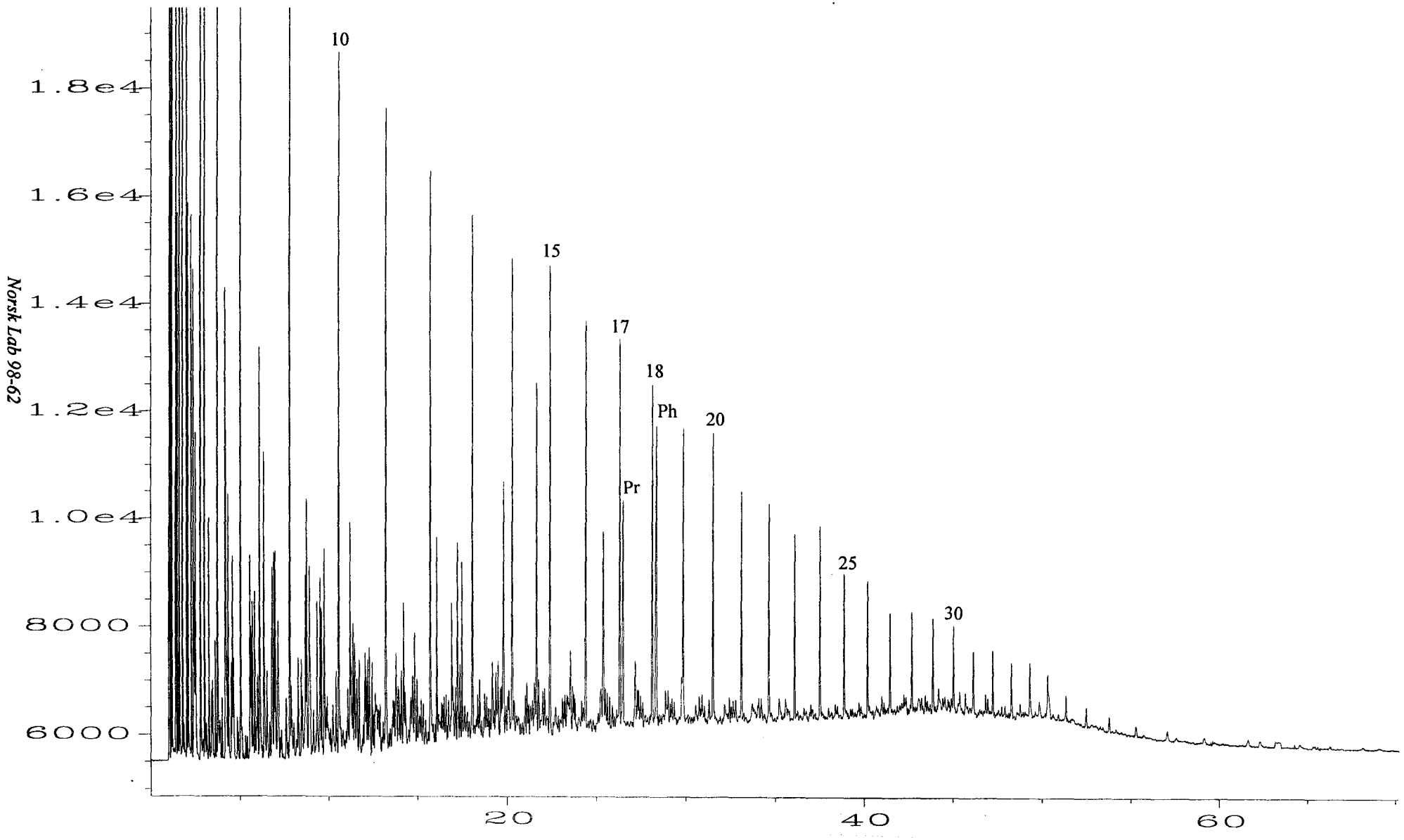

Figure 5: 15/9-19A DST 2B C_{10+} PARAFFIN + NAPHTHENE FRACTION

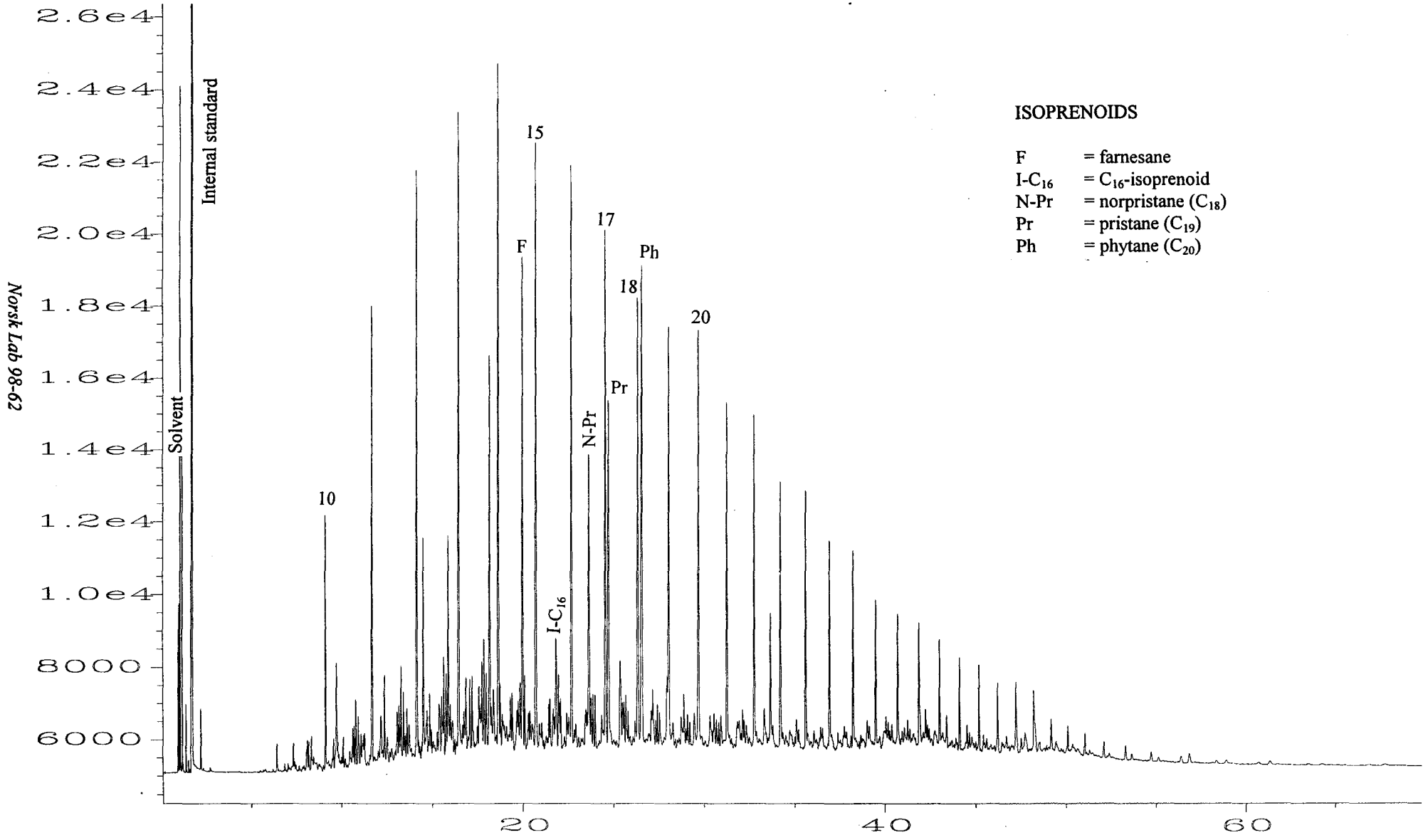

Figure 6: 15/9-19A DST 2B C_{10+} AROMATIC FRACTION

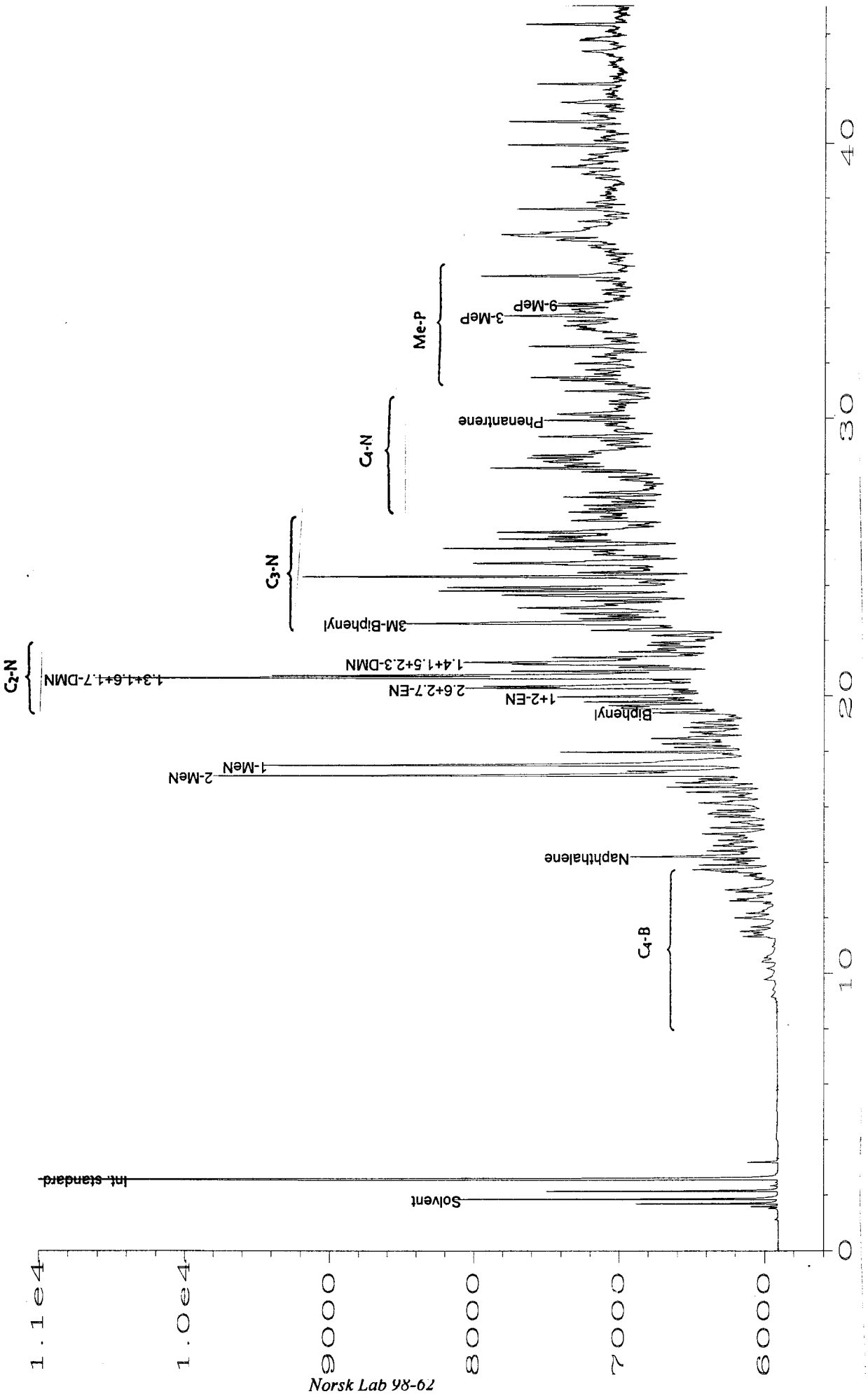

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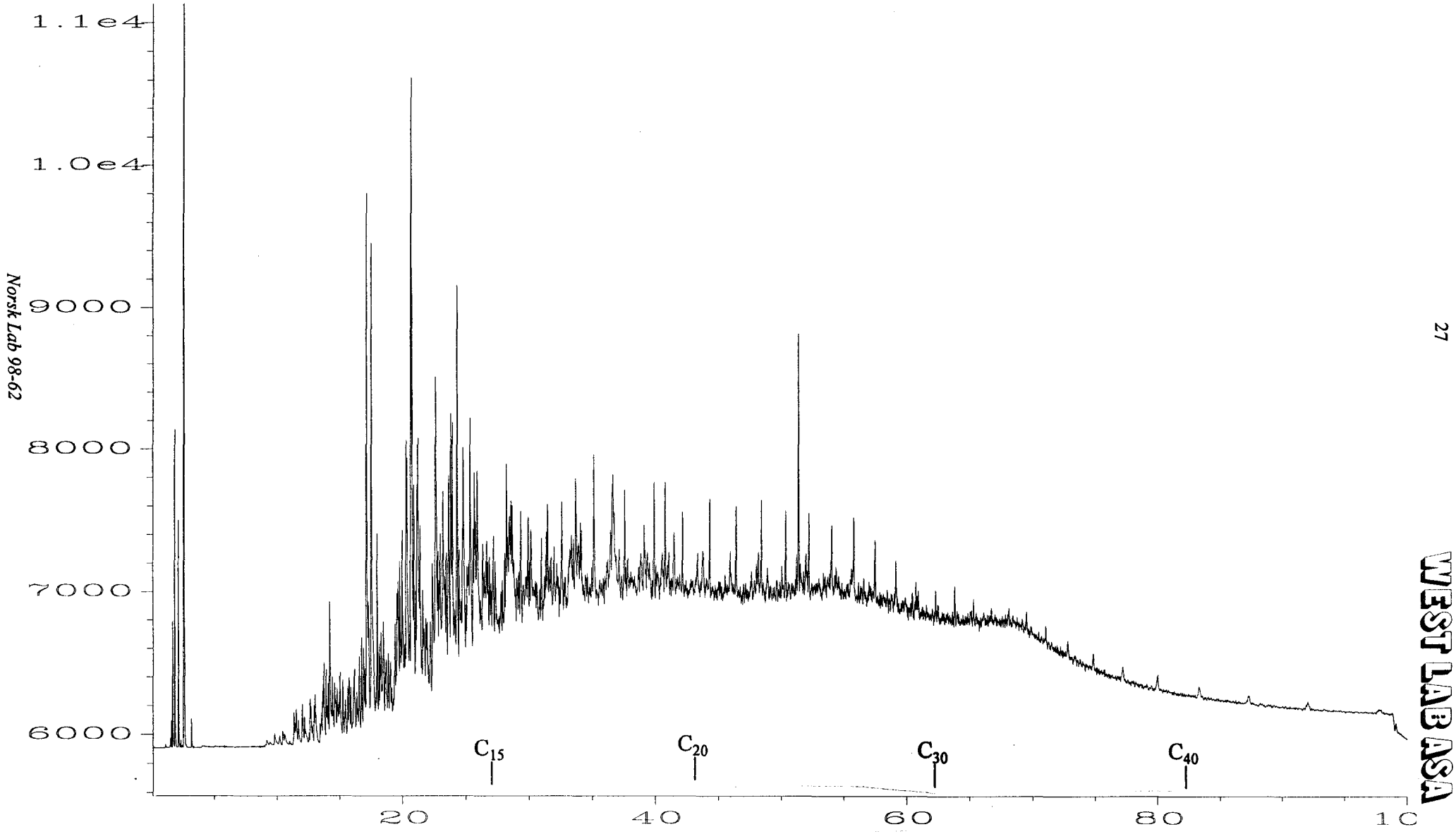
Figure 7: 15/9-19A DST 2B C_{10+} AROMATIC FRACTION



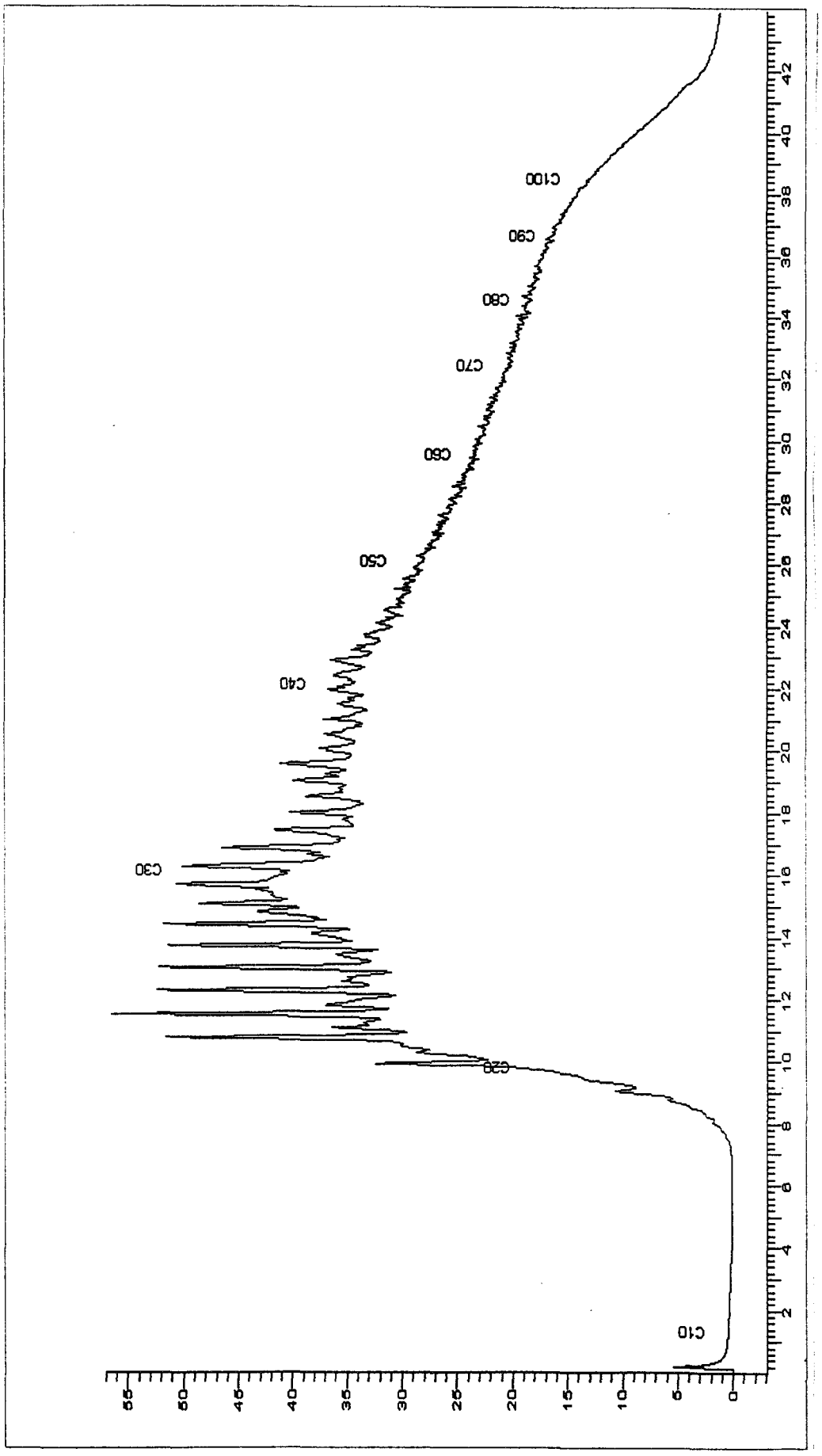
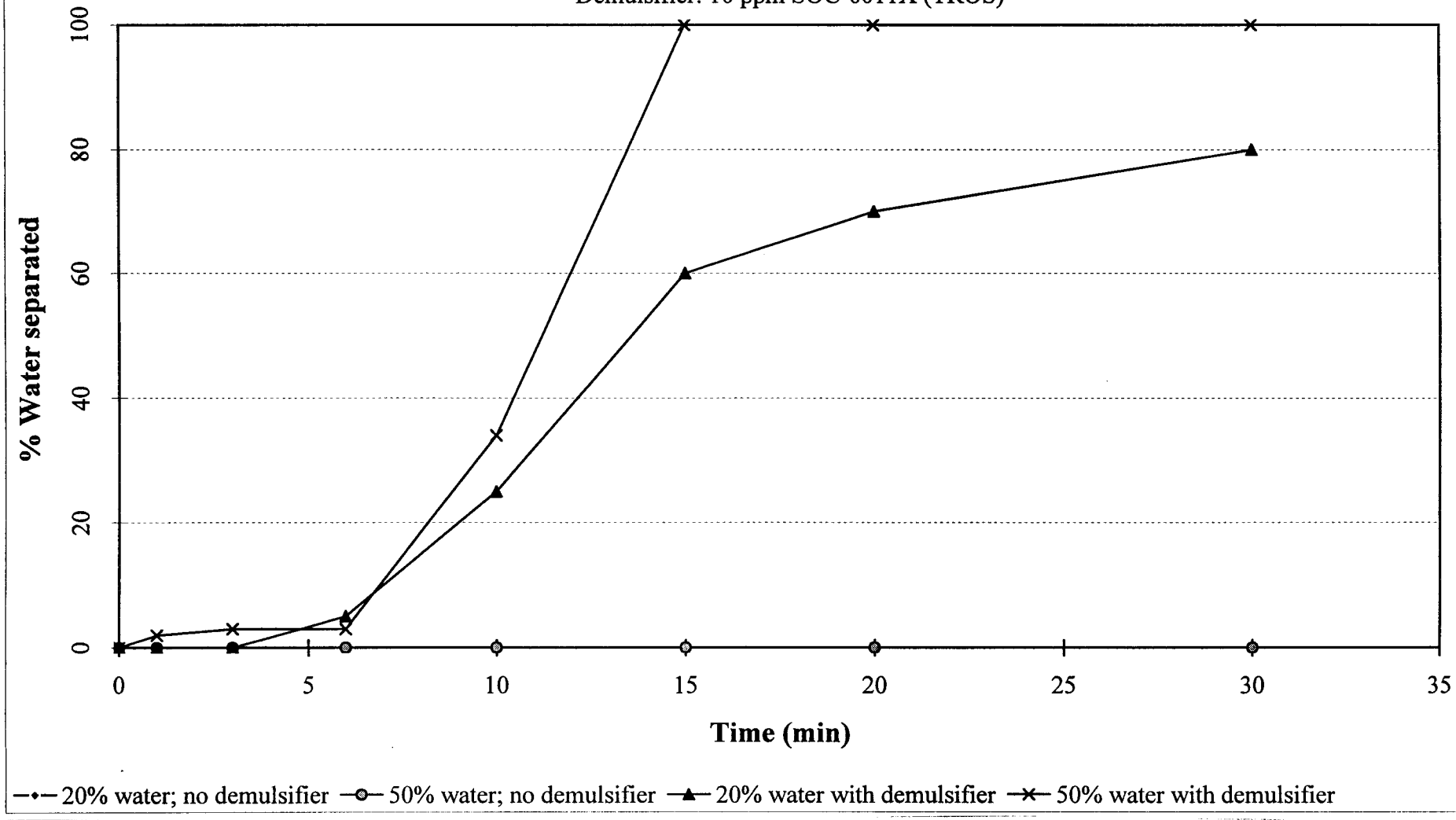


Figure 8: High temperature gas chromatogram of crude oil 15/9-19A DST 2B

Figure 9: CRUDE OIL 15/9-19A DST 2B
Temperature 50°C

Demulsifier: 10 ppm SOC-6011X (TROS)



Appendices

APPENDIX A

Table A.1 Detailed composition of light end of stabilized crude oil 15/9-19A DST 2B

Component Name	Mol Wt g/mole	Density g/cc @ 15C	Type	Weight %	Mole%
C1	16.04	0.26	P	0	0
C2	30.07	0.358	P	0.01	0.08
C3	44.10	0.508	P	0.16	0.92
iC4	58.12	0.563	P	0.09	0.39
nC4	58.12	0.585	P	0.5	2.19
2,2,-DM-C3	72.15	0.597	P	0	0
iC5	72.15	0.625	P	0.41	1.45
nC5	72.15	0.631	P	0.73	2.58
2,2,-DMB	86.18	0.654	P	0	0
Cyc C5	70.13	0.75	N	0.11	0.4
2,3-DMB	86.18	0.666	P	0.03	0.09
2-Me-C5	86.18	0.657	P	0.34	1
3-Me-C5	86.18	0.669	P	0.22	0.65
Unassigned C6 P	86.18	0.664	P	0	0
Unassigned C6 N	86.18	0.664	N	0	0
Unassigned C6 A	86.18	0.664	A	0	0
nC6	86.18	0.664	P	0.73	2.16
Me-Cy-C5	84.16	0.753	N	0.49	1.48
2,4 di Me -C5	100.20	0.677	P	0.02	0.05
2,2,3 Tri-Me-C4	100.20	0.659	P	0	0
Bz	78.11	0.884	A	0.48	1.56
3,3, di Me-C5	100.20	0.698	P	0	0
Cyc C6	84.16	0.783	N	0.3	0.91
2-Me-C6	100.20	0.683	P	0.23	0.58
1,cis-2 Di Me Cyc C5	98.19	0.777	N	0.07	0.18
1,1 Di Me -Cyc C5	98.19	0.759	N	0.01	0.03
3-Me-C6	100.20	0.692	P	0.28	0.71
1,cis-3 Di Me Cyc C5	98.19	0.749	N	0.1	0.26
1,tr-3 Di Me Cyc C5	98.19	0.753	N	0.11	0.29
1,tr-2 Di Me Cyc C5	98.19	0.756	N	0.2	0.52
Unassigned C7 P	100.20	0.688	P	0	0
Unassigned C7 N	100.20	0.688	N	0	0
Unassigned C7 A	100.20	0.688	A	0	0
nC7	100.20	0.688	P	0.79	2.01
Me-Cy-C6	98.19	0.774	N	0.54	1.4
1,1,3 Tri Me Cyc C5	112.21	0.753	N	0.02	0.05
Et Cyc C5	98.19	0.771	N	0.15	0.39
2,5 Di Me C6	114.23	0.698	P	0.04	0.09
2,4 Di Me C6	114.23	0.704	P	0.04	0.09

Cont. table A1	Mol Wt g/mole	Density g/cc @ 15C	Type	Weight %	Mole%
1,tr-2-cis-4- Tri Me Cyc C5	112.21	0.752	N	0.05	0.11
1,tr-2-cis-3- Tri Me Cyc C5	112.21	0.758	N	0.08	0.18
2,3,4 Tri Me C5	114.23	0.723	P	0.01	0.02
Tol	92.14	0.871	A	0.81	2.24
1,1,2 Tri Me Cyc C5	112.21	0.777	N	0.03	0.07
2,3 Di Me C6	114.23	0.716	P	0.03	0.07
2 Me C7	114.23	0.702	P	0.29	0.65
4 Me C7	114.23	0.709	P	0.08	0.18
3,4 Di Me C6	114.23	0.724	P	0.01	0.02
3 Me C7	114.23	0.71	P	0.16	0.36
1,cis-3 Di Me Cyc C6	114.23	0.77	N	0.15	0.33
1, trans- 4 Di Me Cyc C6	112.21	0.767	N	0.06	0.14
1,1 Di Me Cyc C6	112.21	0.785	N	0.01	0.02
1, Me trans-2-Et Cyc C5	112.21	0.773	N	0.15	0.34
1, trans-2-Di Me Cyc C6	112.21	0.78	N	0.07	0.16
Unassigned C8 P	114.23	0.707	P	0.05	0.11
Unassigned C8 N	112.20	0.77	N	0.06	0.14
Unassigned C8 A	114.23	0.707	A	0	0
nC8	114.23	0.707	P	0.69	1.54
1, cis-2 Di Me Cyc C6	112.21	0.8	N	0.03	0.07
1, cis-2 Di Me Cyc C6	112.21	0.8	N	0.02	0.05
Et Cyc C6	112.21	0.79	N	0.4	0.91
1,1,3 Tri Me Cyc C6	126.20	0.783	N	0.12	0.24
ETB	106.17	0.871	A	0.37	0.89
m-Xylene	106.17	0.868	A	0.27	0.65
p-Xylene	106.17	0.868	A	0.07	0.17
4 Me C8	128.26	0.724	P	0.1	0.2
2 Me C8	128.26	0.717	P	0.15	0.3
3 Me C8	128.26	0.724	P	0.19	0.38
o-Xylene	106.17	0.884	A	0.2	0.48
1 Me 3 Et Cyc C6	126.20	0.8	N	0.09	0.18
1 Me 4 Et Cyc C6	126.20	0.79	N	0.04	0.08
Unassigned C9 P	128.26	0.721	P	0.44	0.87
Unassigned C9 N	126.20	0.79	N	0.08	0.16
Unassigned C9 A	128.26	0.721	A	0	0
nC9	128.26	0.721	P	0.69	1.37
C10+	346.00	0.927		86.75	63.81
Totals				100.00	100.00

APPENDIX B

Composition of synthetic formation water used in the emulsion stability test of crude oil 15/9-19A DST 2B

Salt	Concentration g/l
NaCl	118,045
KCl	3,337
$CaCl_2 \cdot 2H_2O$	28,758
$MgCl_2 \cdot 6H_2O$	19,986
$BaCl_2 \cdot 2H_2O$	0,027
$SrCl_2 \cdot 6H_2O$	0,971

Based on composition of formation water from well 15/9-19A.

APPENDIX C

A brief description of analytical methods.

1. Distillation
TBP Distillation is performed using a semi automatic MK IV distillation system comprising 25 mm distillation Still and controller from H.S. Martin Inc. (New Jersey, USA). The system operates in accordance with the requirements of ASTM Method D2892 and at operating conditions produces around 15 theoretical plates.

Distillation is performed up to n-C_9 at atmospheric pressure to produce a C_{10+} fraction. It is then continued at 100 mmHg up to n-C_{12} and at 10 mmHg up to n-C_{19} producing a C_{20+} residue. Reflux ratios vary from 6:1 down to 4:1 as the distillation progresses. Cut points for each fraction are taken at atmospheric equivalent temperatures reported by Katz and Firoozabadi and are reported in **table 3.** Direct measurements of the C_{10+} and C_{20+} molecular weight and density are performed. Corrections for overlap from chromatographic analysis of the fractions were made to produce a `pure` C10+ weight % molecular weight and density.

2. Gas Chromatogram of whole oil is recorded using a CP Sil 5 CB column (25 m x 0,23 mm i.d., 0,13 µm filmthickness) and FI-detector **(ref. 7)**.
The following temperature programme is used:

10 °C 2 min
6 °C/min to 300 °C
Injector (split): 300 °C
Detector: 320 °C

A gas chromatographic analysis is also performed on the whole oil sample to obtain a detailed composition of the C_9 minus fraction. The physical properties of the C_4-C_9 fractions are calculated from the detailed component breakdown. The C_{10+} wt% composition is adjusted to conform to the value measured from the the distillation.

The whole oil GC analysis is performed using a megabore capillary column (DB-1 liquid phase, 30 m x 0,53 mm i.d.) and the detailed component breakdown is performed using Chrompack SIL narrow bore capillary column (50 x 0,25 i.d.).

3. High-temperature gas chromatographic analysis of C_{20+} is carried out on a Carlo Erba Mega Series Chromatograph with a 5 m x 0.5 mm i.d. WCOT Ultimetal. HT-SIMDIST CB (Modified ASTM D5307).

Temperature program:
35 °C 2 min
5 °/min to 390 °C
390 °C 20 min
10 °/min to 430 °C
430 °C 10 min
Detector, FID: 400 °C
The C_{20+} samples are analyzed using combined C_{13}-C_{14} fraction as internal standard.

4. Molecular weights are determined by freezing point depression of benzene (Cryette, Precision Instr.), except for C_4-C_9 which are calculated from GC composition. Precision of the method is about 1,5 % (RSD) for residues and about 1 % for lower fractions.

5. Densities of liquid fractions are measured using a Paar DMA 48 frequency densitometer, thermostated at 15 °C. Precision of the method is +/- 0.0002 g/cc. Densities of the C_4-C_9 fractions are calculated from the GC composition. Density of the C_{20+} residue is measured by IP 190 (pyknometer).

6. Water content (wt %) is determined by Karl Fischer titration.

7. Sulphur content is determined by X-ray fluorescence (Siemens SRS 300,ASTM D2622, rev 3).

8. Wax Content is determined by a modified UOP method 46-64, **(ref. 8 and 9)**, the acetone precipitation technique. The wax is precipitated with acetone at -25 °C and filtrated. The precipitate is purified by elusion through a short silica cartridge.

9. Thermal pretreatment (benefication) of crude oil. Separator oil collected in 20 litre Xample-bottle is depressurized in one step to atmospheric pressure and room temperature after being heated to about 60 °C in the bottle. The stabilized crude oil is transferred to a 1 litre gas-tight stainless steel pretreatment cell. It is emphasized to conduct the transfer quickly in order to minimize exposure to air and light which may cause oxidation processes to occur with formation of surface active species. The crude is topped with nitrogen and heated to 80 °C for 2 hours in order to dissolve wax and thus erase the memory of previous wax formation. Finally, the oil is cooled at a rate of 12.6 °C/hour to the actual test temperature before transfer to the various instruments (pour point, viscosity).

10. Pour poin : The method to determine the Pour Point is a modified version (**ref. 9**) of ASTM D97 (**ref. 10**):
- The Pour point "as received" is the Pour point measured on the untreated oil (no thermal pretreatment).
- The Minimum Pour point is the Pour point measured after controlled cooling from 80 °C.
- The Maximum Pour point is the Pour point measured after reheating the oil to 50 °C followed by controlled recooling.

11 a. Wax precipitation temperature (WPT) is determined by polarization microscopy. The sample is cooled at a rate of 0.5 °C/min after first being heated to 70 °C. For detailes, see **ref. 9.**

11 b. Wax dissolution temperature (WDT) is determined in the same way as WPT. When WPT has been established, the sample is left at room temperature for at least 30 minutes, and then reheated at a rate of 0.5 °C/min.

12. Kinematic viscosity is measured in the Newtonian temperature range using a Ubbelohde glass capillary viscometer with an appropriate capillary constant. The viscometer tubes are kept in a thermostated bath for 15 minutes at each temperature prior to measurements, which are run four times. The kinematic viscosity is related to dynamic viscosities as follows :

Dyn. visc. (mPa s) = Kin.visc.(cSt)*Density (g/cm^3).
$cSt = 10^{-2}\ mm^2/s$.

13. Apparent viscosity of thermally beneficiated oil is measured with Paar Physica USD (Universal Dynamic Specrometer) 200 reometer with Z1 DIN (double gap) sylinder. The heater/cooler is a LAUND RC6 CP with siliconoil as medium. Viscosity vs. temperature at various shear rates is run in the non-Newtonian temperature range of the oil.

14. Pentane insolubles (asphaltenes) are precipitated with pentane at room temperature (1:40 vol:vol) and filtrated through a 0,45 µm filter. The precipitated material is dissolved in toluene, followed by precipitation with pentane and a new filtration through a 0,45 µm filter.

15 a. Hydrocarbon group type analysis of C_{10+}, C_{20+} and distillation-fractions are performed by preparative liquid chromatography using a silica column to separate aromatics from saturates (paraffins/naphthenes). The polar fraction is estimated from the correlation between the aromatic and the polar fraction (**ref. 4**). The solvent is removed by vacuum evaporation, and the fractions quantified by weighing. Residual hexane is determined by GC with internal standard.

15 b. Hydrocarbon group type analysis of distillation fractions C_{10} to C_{19} is performed by gas chromatography-mass spectrometry using regular electron impact ionisation. The distribution of paraffins and naphthenes as well as a series of aromatic subclasses are determined. The aliphatic compounds are determined by intergration of the most intense fragment ions. A matrix calculation is then used to correct for interferences between the aliphatic compounds (**ref. 3**).

Experimental conditions :

Mass spectrometer	: Finnigan MAT SSQ 700
Inlet system	: Varian 3400
Data system:	: DecStation 5000/133

Temp.prog.GC	: 30 °C 2 min.,4 °C/min. to 250 °C- 250 °C 15 min.
Injector temp.	: 275 °C
Ion source temperature	: 150 °C
Ionization potential	: 70 eV
Resolution	: 500
Scan rate	: 35-350
Scanning	: 0.5 sec./scan
Carrier gas	: Helium
Column	: 30m DB-5 MS, 0,25 µm film, 0,25 mm i.d., 12 psi
Injection	: 1 µl, split 50 ml/min

16. Nitrogen bases in hydrocarbons is determined by potentiometric titration, UOP Method 269-70T, (**ref. 12**). Organic bases are titrated potentiometrically in an anhydrous medium employing glacial acetic acid as the solvent. The electrode system is glass vs. calomel.

17. Acid Number of Petroleum Products is determined by Potentiometric Titration, ASTM Method D664-87, (**ref. 13**). The sample is dissolved in a mixture of toluene and isopropyl alchohol, containing a small amount of water and titrated potentiometrically with alcoholic potassium hydroxide. The electrode system is glass vs. calomel.

18. Emulsion stability test :

Equipment:

Homogenizer:	Propeller type - Buhler HO4 incl.Heto temp.controller and circulator.
Circulator bath:	Heto Lab. Equipment

Experimental procedures:

The crude oil was sampled directly from the pressurized bottle (a single flash to ambient conditions). A representative sample of the "flashed" oil was added to an appropriate volume of synthetic formation water in the homogenizer and kept at the specified temperature.

Standard emulsification conditions are :

Propeller speed	: 8000 rpm
Mixing time	: 1 min.
Mixing volume	: 11 cm^3
Temperature	: 50 °C
Water cut	: 20 % and 50 %

After homogenizing, the emulsion was transferred to a preheated, screw capped, graded glass vial (10 cm^3). The demulsifier was added immediately after emulsification by shaking for 30 seconds and placed in a thermostated bath kept at the specified temperature (50 °C). The separation of free water was recorded as a function of time for 30 minutes. The demulsifier was diluted with xylene. 10µl xylene solution was added, giving the wanted concentration of demulsifier (10 ppm). Synthetic formation water was mixed according to the recipe given in Appendix B.

APPENDIX D

Definition of Carbon Preference Indices :

$$CPI\ 1 = 1/2((C_{25}+C_{27}+C_{29}+C_{31}) / (C_{24}+C_{26}+C_{28}+C_{30}) + (C_{25}+C_{27}+C_{29}+C_{31}) / (C_{26}+C_{28}+C_{30}+C_{32}))$$

$$CPI\ 2 = 2\ C_{27} / (C_{26}+C_{28})$$

Definition of Methyl Phenantrene Indices :

$$MPI\ 1 = \frac{1.5\ (2\text{-MP} + 3\text{-MP})}{P + 9\text{-MP} + 1\text{-MP}}$$

$$MPI\ 2 = \frac{3(2\text{-MP})}{P + 9\text{-MP} + 1\text{-MP}}$$

Enclosures

CORE LABORATORIES (U.K.) LIMITED
Advanced Technology Centre

T.B.P. Distillation Study

for

Den Norske Stats Oljeselskap a.s.

Our File : RFLA 980008

Well : 15/9-19A
Sleipner

98-62

CORE LABORATORIES (U.K.) LIMITED
Advanced Technology Centre

16th February 1998

Den Norske Stats Ojleselskap a.s.
N-4035
Stavanger
NORWAY

Subject : Distillation Study
Well : 15/9-19A
Contract : DTJ017535
Our File : RFLA 980008

Attention : Ms. Brit Bjorndal

Dear Madam,

Core Laboratories have recently completed a high temperature fractional distillation study on fluids from well 15/9-19A, the results of which are presented in this report.

The laboratory data is presented in the report as follows :-

Table 1	:	Distillation Data
Table 2	:	Molecular Weight and Density Properties
Table 3	:	Wt% overlap between fractions
Table 4	:	Detailed Compositional Analysis of Whole Oil inc. Thompsons Indices
Table 5	:	PNA Distribution
Appendix 1	:	Summary of Laboratory Procedures

We trust that our service has met with your approval and look forward to the opportunity of working with Den Norske Stats Ojleselskap a.s. again in the future.

Yours faithfully,

Core Laboratories (U.K.) Limited

Andy Williamson
Snr. Fluids Supervisor -
Exploration and Production Chemistry Group

Statoil
File : RFLA 980008
Well : 15/9-19A

High Temperature Fractional Distillation Data

Table 1

Cut	Temp deg C	Wt%	Cum Wt%	Density	Vol%	Cum Vol%	Mol Wt	Mole %	Cum Mol %
C4-		0.76	0.76	0.560	1.21	1.21	53.9	3.58	3.58
C5		1.14	1.90	0.628	1.62	2.83	72.2	4.03	7.61
C6	69.2	1.43	3.33	0.669	1.91	4.74	84.7	4.30	11.91
C7	98.9	3.08	6.41	0.743	3.70	8.44	91.4	8.58	20.49
C8	126.1	3.58	9.99	0.764	4.19	12.63	105.0	8.70	29.19
C9	151.3	3.26	13.25	0.775	3.76	16.39	118.8	7.00	36.19
C10+	>151.3	86.75	100.00	0.927	83.61	100.00	346.0	63.81	100.00
C10	174.6	2.72	15.97	0.783	3.08	19.47	131.4	5.26	41.45
C11	196.4	2.64	18.61	0.796	2.95	22.42	146.2	4.61	46.06
C12	216.8	2.55	21.16	0.811	2.80	25.22	159.7	4.07	50.13
C13	235.9	2.54	23.70	0.823	2.74	27.96	173.4	3.73	53.86
C14	253.9	2.62	26.32	0.832	2.80	30.76	185.6	3.59	57.45
C15	271.0	3.19	29.51	0.850	3.33	34.09	198.5	4.09	61.54
C16	287.3	2.79	32.30	0.851	2.92	37.01	218.5	3.26	64.80
C17	303.0	2.96	35.26	0.853	3.08	40.09	235.7	3.20	68.00
C18	317.0	2.56	37.82	0.863	2.63	42.72	249.4	2.61	70.61
C19	331.0	2.15	39.97	0.878	2.17	44.89	260.2	2.10	72.71
C20+	>331.0	60.03	100.00	0.973	54.82	99.71	569.5	26.58	99.29

Core Laboratories (U.K.) Limited

Statoil
File : RFLA 980008
Well : 15/9-19A Sleipner

Table 2

Measured and Calculated Molecular Weights and Densities of Crude Oil ex Well 15/9-19A

	Whole Oil	C10+ Fraction	C20+ Fraction
Measured MWt	257	346	570
Calc MWt using C10+ MWt	255	-	-
Calc MWt using C20+ MWt	256	349	-
Measured Density	0.891	0.927	0.973
Calc density using C10+ density	0.893	-	-
Calc density using C20+ density	0.892	0.925	-

Statoil
File : RFLA 980008
Well : 15/9-19A Sleipner

Table 3

Wt% Overlap between Distillation Fractions

of Crude Oil ex Well 15/9-19A Sleipner

Fraction	Weight %	Cn-1 Rel %	Cn Rel %	Cn+1 Rel %
C4-	0.76	-	-	-
C5	1.14	-	-	-
C6	1.43	0	100	0
C7	3.08	0	100	0
C8	3.58	0	100	0
C9	3.26	0	100	0
C10	2.72	0	100	0
C11	2.64	17	64	19
C12	2.55	18	60	22
C13	2.54	17	60	23
C14	2.62	21	55	24
C15	3.19	19	52	29
C16	2.79	21	41	38
C17	2.96	30	30	40
C18	2.56	27	28	45
C19	2.15	28	34	38

Detailed Compositional Analysis

Component Name	Mol Wt g/mole	Density g/cc @ 15C	Type	Weight %	Mole%
C1	16.04	0.260	P	0.00	0.00
C2	30.07	0.358	P	0.01	0.08
C3	44.10	0.508	P	0.16	0.92
iC4	58.12	0.563	P	0.09	0.39
nC4	58.12	0.585	P	0.50	2.19
2.2.-DM-C3	72.15	0.597	P	0.00	0.00
iC5	72.15	0.625	P	0.41	1.45
nC5	72.15	0.631	P	0.73	2.58
2.2,-DMB	86.18	0.654	P	0.00	0.00
Cyc C5	70.13	0.750	N	0.11	0.40
2.3-DMB	86.18	0.666	P	0.03	0.09
2-Me-C5	86.18	0.657	P	0.34	1.00
3-Me-C5	86.18	0.669	P	0.22	0.65
Unassigned C6 P	86.18	0.664	P	0.00	0.00
Unassigned C6 N	86.18	0.664	N	0.00	0.00
Unassigned C6 A	86.18	0.664	A	0.00	0.00
nC6	86.18	0.664	P	0.73	2.16
Me-Cy-C5	84.16	0.753	N	0.49	1.48
2.4 di Me -C5	100.20	0.677	P	0.02	0.05
2.2.3 Tri-Me-C4	100.20	0.659	P	0.00	0.00
Bz	78.11	0.884	A	0.48	1.56
3,3, di Me-C5	100.20	0.698	P	0.00	0.00
Cyc C6	84.16	0.783	N	0.30	0.91
2-Me-C6	100.20	0.683	P	0.23	0.58
1,cis-2 Di Me Cyc C5	98.19	0.777	N	0.07	0.18
1,1 Di Me -Cyc C5	98.19	0.759	N	0.01	0.03
3-Me-C6	100.20	0.692	P	0.28	0.71
1.cis-3 Di Me Cyc C5	98.19	0.749	N	0.10	0.26
1.tr-3 Di Me Cyc C5	98.19	0.753	N	0.11	0.29
1.tr-2 Di Me Cyc C5	98.19	0.756	N	0.20	0.52
Unassigned C7 P	100.20	0.688	P	0.00	0.00
Unassigned C7 N	100.20	0.688	N	0.00	0.00
Unassigned C7 A	100.20	0.688	A	0.00	0.00
nC7	100.20	0.688	P	0.79	2.01
Me-Cy-C6	98.19	0.774	N	0.54	1.40
1.1.3 Tri Me Cyc C5	112.21	0.753	N	0.02	0.05
Et Cyc C5	98.19	0.771	N	0.15	0.39
2.5 Di Me C6	114.23	0.698	P	0.04	0.09
2.4 Di Me C6	114.23	0.704	P	0.04	0.09
1.tr-2-cis-4- Tri Me Cyc C5	112.21	0.752	N	0.05	0.11
1.tr-2-cis-3- Tri Me Cyc C5	112.21	0.758	N	0.08	0.18
2.3.4 Tri Me C5	114.23	0.723	P	0.01	0.02
Tol	92.14	0.871	A	0.81	2.24
1.1.2 Tri Me Cyc C5	112.21	0.777	N	0.03	0.07
2.3 Di Me C6	114.23	0.716	P	0.03	0.07
2 Me C7	114.23	0.702	P	0.29	0.65
4 Me C7	114.23	0.709	P	0.08	0.18
3.4 Di Me C6	114.23	0.724	P	0.01	0.02
3 Me C7	114.23	0.710	P	0.16	0.36
1.cis-3 Di Me Cyc C6	114.23	0.770	N	0.15	0.33
1. trans- 4 Di Me Cyc C6	112.21	0.767	N	0.06	0.14
1,1 Di Me Cyc C6	112.21	0.785	N	0.01	0.02
1. Me trans-2-Et Cyc C5	112.21	0.773	N	0.15	0.34
1. trans-2-Di Me Cyc C6	112.21	0.780	N	0.07	0.16
Unassigned C8 P	114.23	0.707	P	0.05	0.11
Unassigned C8 N	112.20	0.770	N	0.06	0.14
Unassigned C8 A	114.23	0.707	A	0.00	0.00
nC8	114.23	0.707	P	0.69	1.54
1. cis-2 Di Me Cyc C6	112.21	0.800	N	0.03	0.07
1. cis-2 Di Me Cyc C6	112.21	0.800	N	0.02	0.05
Et Cyc C6	112.21	0.790	N	0.40	0.91
1.1.3 Tri Me Cyc C6	126.20	0.783	N	0.12	0.24
ETB	106.17	0.871	A	0.37	0.89
m-Xylene	106.17	0.868	A	0.27	0.65
p-Xylene	106.17	0.868	A	0.07	0.17
4 Me C8	128.26	0.724	P	0.10	0.20
2 Me C8	128.26	0.717	P	0.15	0.30
3 Me C8	128.26	0.724	P	0.19	0.38
o-Xylene	106.17	0.884	A	0.20	0.48
1 Me 3 Et Cyc C6	126.20	0.800	N	0.09	0.18
1 Me 4 Et Cyc C6	126.20	0.790	N	0.04	0.08
Unassigned C9 P	128.26	0.721	P	0.44	0.87
Unassigned C9 N	126.20	0.790	N	0.08	0.16
Unassigned C9 A	128.26	0.721	A	0.00	0.00
nC9	128.26	0.721	P	0.69	1.37
C10+	346.00	0.927		86.75	63.81
Totals				100.00	100.00

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Detailed Compositional Analysis

PNA Analysis of C9 Minus

Group	Weight% PNA Distribution			Total
	P	N	A	
C1	0.00	0.00	0.00	0.00
C2	0.01	0.00	0.00	0.01
C3	0.16	0.00	0.00	0.16
C4	0.59	0.00	0.00	0.59
C5	1.14	0.00	0.00	1.14
C6	1.32	0.11	0.00	1.43
C7	1.32	1.28	0.48	3.08
C8	1.40	1.37	0.81	3.58
C9	1.57	0.78	0.91	3.26
Total	7.51	3.54	2.20	13.25

Group	Mole% PNA Distribution			Total
	P	N	A	
C1	0.00	0.00	0.00	0.00
C2	0.08	0.00	0.00	0.08
C3	0.92	0.00	0.00	0.92
C4	2.58	0.00	0.00	2.58
C5	4.03	0.00	0.00	4.03
C6	3.90	0.40	0.00	4.30
C7	3.35	3.67	1.56	8.58
C8	3.13	3.33	2.24	8.70
C9	3.12	1.69	2.19	7.00
Total	21.11	9.09	5.99	36.19

Group	PNA Density Data		
	P	N	A
C1	-	-	-
C2	-	-	-
C3	-	-	-
C4	-	-	-
C5	-	-	-
C6	0.6631	0.7500	-
C7	0.6878	0.7613	0.8840
C8	0.7065	0.7710	0.8710
C9	0.7212	0.7907	0.8696

Group	PNA MWt Data		
	P	N	A
C1	-	-	-
C2	-	-	-
C3	-	-	-
C4	-	-	-
C5	-	-	-
C6	86.18	70.13	-
C7	100.20	89.03	78.11
C8	114.23	104.87	92.14
C9	128.26	117.73	106.17

Thompson Index Key

A - Benzene / n-Hexane
B - Toluene / n-Heptane
X - m+p Xylene / n-Octane
C - (nC6 + nC7) / (CycC6 + MeCycC6)
I' - 3MeC6 / (1cis3 + 1t3 + 1t2DiMeCycC5)
I - (2MeC6 + 3MeC6) / (1cis3 + 1t3 + 1t2DiMeCycC5)
F - n-Heptane / MeCycC6
H - (100 x nC7) / (sumC7 - (MeCycC5 + 2,4DiMeC5 + Bz) + MeCycC6)
U - CycC6 / MeCycC5
R - nC7 / 2MeC6
R' - nC7 / 3MeC6
W - Benzene / CycC6

Thompson Index	Value
A	0.658
B	1.025
X	0.493
C	1.810
I'	0.683
I	1.244
F	1.463
H	30.038
U	0.612
R	3.435
R'	2.821
W	1.600

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Table 5

Compositional Analysis of Stab Crude Oil ex 15/9-19A by Gas Chromatography

Component Gp	Weight %	Molecular Weight	Density
C1	0.00	16.0	0.260
C2	0.01	30.1	0.350
C3	0.16	44.1	0.508
iC4	0.09	58.1	0.563
nC4	0.50	58.1	0.585
2,2-DM-C3	0.00	72.2	0.597
iC5	0.41	72.2	0.625
nC5	0.73	72.2	0.631
Hexanes Total	1.43	84.7	0.669
Hexanes - P	1.32	86.2	0.663
Hexanes - N	0.11	70.1	0.750
Heptanes Total	3.08	91.4	0.743
Heptanes - P	1.32	100.2	0.688
Heptanes - N	1.28	89.0	0.761
Heptanes - A	0.48	78.1	0.884
Octanes Total	3.58	105.0	0.764
Octanes - P	1.40	114.2	0.707
Octanes - N	1.37	104.9	0.771
Octanes - A	0.81	92.1	0.871
Nonanes Total	3.26	118.8	0.775
Nonanes - P	1.57	128.3	0.721
Nonanes - N	0.78	117.7	0.791
Nonanes - A	0.91	106.2	0.870
Decanes Plus	86.75	346.0	0.927

Note :
Decanes plus properties and wt% from distillation corrected for overlap between C9 and C10

Statoil
File : RFLA 980008
Well : 15/9-19A

Appendix 1

Summary of Laboratory Procedures

i. Distillation

TBP Distillation is performed using a semi automatic MK IV distillation system comprising 25mm distillation Still and controller from H.S. Martin Inc. (New Jersey, USA). The system operates in accordance with the requirements of ASTM Method D2892 and at operating conditions produces around 15 theoretical plates.

Distillation is performed up to nC9 at atmospheric pressure to produce a C10+ fraction. It is then continued at 100mm Hg up to nC12 and at 10 mm Hg up to nC19 producing a C20+ residue. Reflux ratios vary from 6:1 down to 4:1 as the distillation progresses. Cut points for each fraction are taken at atmospheric equivalent temperatures reported by Katz and Firoozabadi and are reported in Table 1.

Direct measurements of the C10+ and C20+ molecular weight and density are performed. Corrections for overlap from chromatographic analysis of the fractions were made to produce a 'pure' C10+ weight %, molecular weight and density.

ii. Chromatographic Analysis

A gas chromatographic analysis is performed on the whole oil sample to obtain a detailed composition of the C9 minus fraction. The physical properties of the C4 - C9 fractions are calculated from the detailed component breakdown. The C10+ wt% composition is adjusted to conform to the value measured from the distillation.

The whole oil GC analysis is performed initially using a megabore capillary column (DB-1 liquid phase, 30M x 0.53mm i.d.) with temp programming as follows; 35°C held for 2 mins with temp programming at 15°C/min up to 300°C. Hold 300°C for 70 mins.

The detailed component breakdown is performed using a Chrompack narrow bore capillary column (CP-SIL 5CB liquid phase, 50M x 0.25mm i.d.) with temp programming as follows: 30°C held for 7 mins with temp programming at 3°C/min up to 320°C. Hold 320°C for 70 mins.

iii. Molecular Weights

Molecular weights for C4 to C9 fractions were calculated from the detailed compositional analysis. Molecular weights for the C10 - C19 fractions, C10+ and C20+ residues were measured by Depression of Freezing Point of Benzene (Cryette, Precision Systems instrument).

CORE LABORATORIES (U.K.) LIMITED
Advanced Technology Centre

Den Norske Stats Oljeselskap a.s.

RFLA : 980008

15/9-19A Sleipner

Core Laboratories (U.K.) Limited

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Snr. Fluids Supervisor -
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PKS RAPPORT
PRODUKTTEKNISK KOMPETANSE OG SERVICE SENTER

Rapportnummer: 811-015
Gradering:

STATOIL - MARKETING
Tlf: 56 34 46 00
Telefax: 56 36 20 50

Rapportens tittel:
High temperature simulated destillation
Well 15/9-19A

Seksjon:	**Dato:**	**Antall sider og bilag:**
RP	30.03.98	5

Utarbeidet av:
30.03.98
Kjell Arne Ulvund
Kjell Arne Ulvund

Godkjent av:
30.03.98 Connie Thomsen
Connie Thomsen

Prosjekt/Oppdrag:

Oppdragsgiver:	**Oppdragsgiver ref:**
WestLab v/A.M. Eide	Ordre 1998-62 DTJ020215

Kort sammendrag:

Stikkord:
HTSIMDIST

ANALYSIS REPORT

High temperature simulated destillation

Date: 30.03.98
Work description: High temperature simulated destillation
Well 15/9-19A

Customer: WestLab v/A.M. Eide

PKS contract no.: 811-015
Samples received: 10.02.98

The sample is analysed according to ASTM5307 modified to account for a higher end boiling point.
The sample is analysed with and without an internal standard and the residual fraction (>C100, 725 °C) is calculated.
Data from C1 to C19 provided from Core Lab.

RESULTS

SAMPLE	Final Boiling Point (°C)	Residual Fraction (>720 °C)
Well 15/9-19A	NA	3,3

Simulated distillation by high-temperature GC analysis
Sample: Well 15/9-19A

Fraction	% of crude oil (w/w)	% Cumulative (w/w)	Boiling Point (°C)
Gas	0,76	0,76	
C5	1,14	1,90	36,5
C6	1,43	3,33	69,2
C7	3,08	6,41	98,9
C8	3,58	9,99	126,1
C9	3,26	13,25	151,3
C10	2,73	15,98	174,6
C11	2,64	18,62	196,4
C12	2,55	21,17	217,2
C13	2,54	23,71	235,9
C14	2,62	26,33	253,9
C15	3,19	29,52	271,1
C16	2,79	32,31	287,3
C17	2,96	35,27	303,0
C18	2,56	37,83	317,0
C19	2,15	39,98	331,0
C20	0,93	40,91	344
C21	1,64	42,56	357
C22	1,75	44,31	369
C23	2,01	46,32	381
C24	1,58	47,90	391
C25	1,67	49,58	402
C26	1,58	51,16	412
C27	1,09	52,25	423
C28	0,77	53,02	431
C29	2,87	55,89	441
C30	2,18	58,07	449
C31	1,51	59,58	457
C32	1,55	61,13	466
C33	1,40	62,53	474
C34	1,25	63,78	481
C35	1,37	65,15	489
C36	1,15	66,30	496
C37	1,08	67,38	502
C38	1,25	68,62	509
C39	1,17	69,79	516
C40	1,02	70,81	522
C41-45	4,94	75,75	551
C46-50	3,77	79,53	575
C51-55	3,08	82,60	596
C56-60	2,61	85,21	615
C61-65	2,17	87,38	632
C66-70	1,83	89,21	647
C71-75	1,67	90,88	661
C76-80	1,45	92,34	675
C81-85	1,23	93,57	688
C86-90	1,22	94,79	700
C91-95	1,02	95,81	710
C96-100	0,86	96,68	720
C100+	3,32	100,00	720+

Simulated distillation plot

Well 15/9-19A

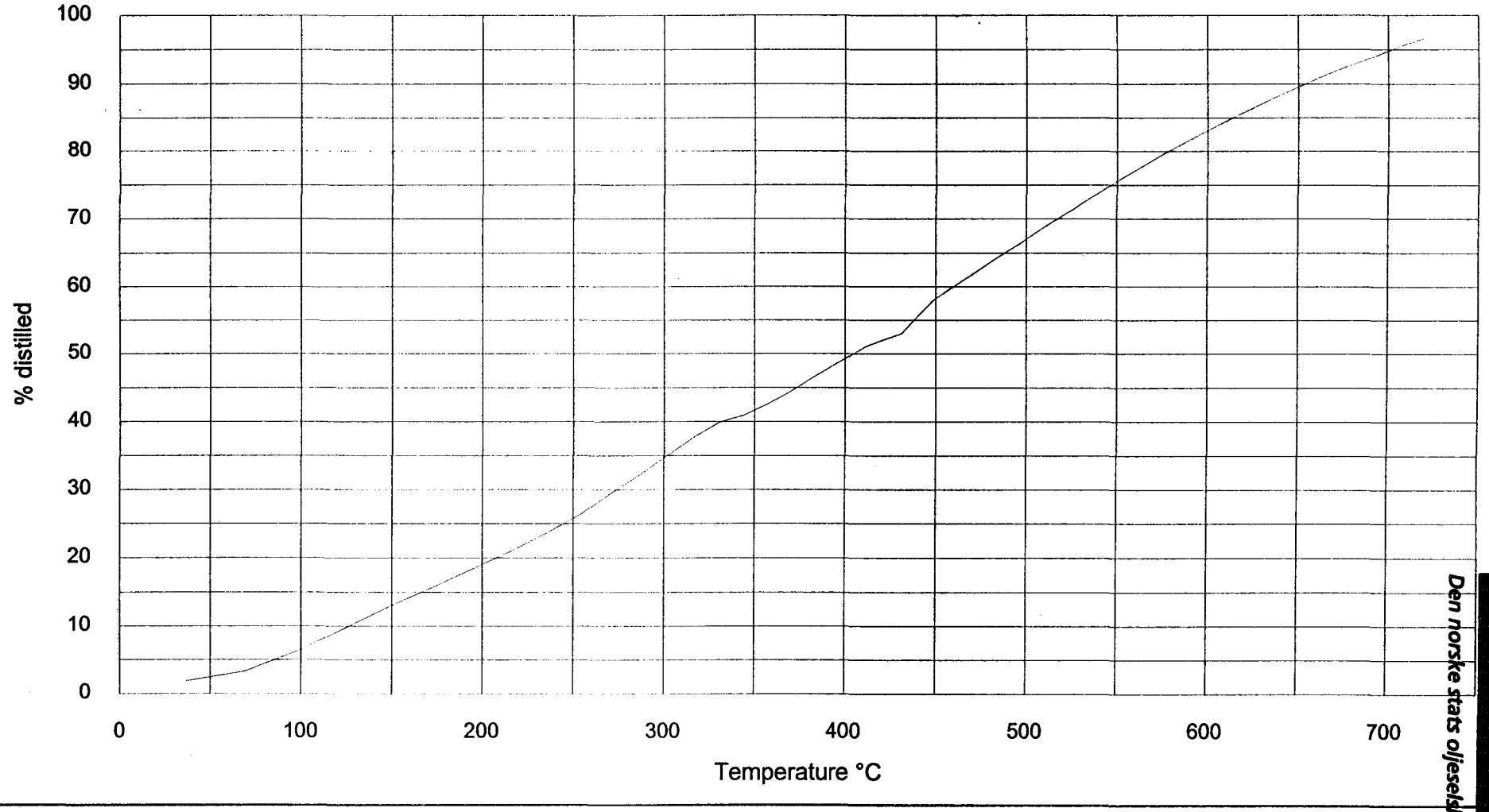

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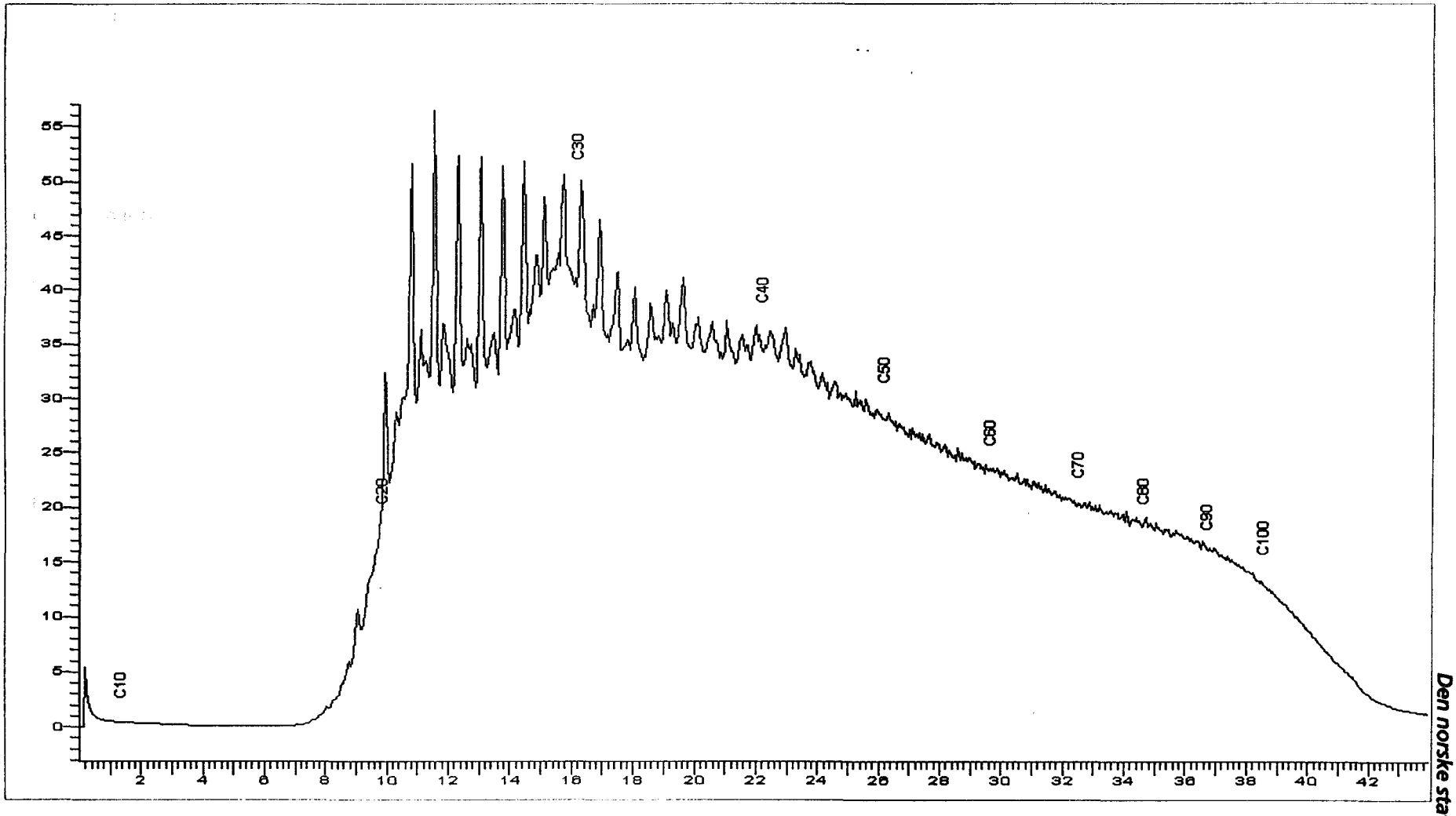
FIGURE 1. Chromatogram of C20+ Well 15/9-19A



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Report

Your ref.:	Our ref.:	Direct line:	Oslo,
1998-62 DTJ020215	HVD	22 06 76 96	1998-02-26

Project no.:
664022.00

Project title:
Analysis of C_{10}-C_{19} fractions

Sample series:
1998-86 (1-10)

Summary

A total of 10 fractions (C_{10} - C_{19}) have been analysed by GC-MS for content of paraffins, naphthenes and different aromatic groups.

Introduction

The samples were received on February 10th for analysis of the main hydrocarbon types by gas chromatography-mass spectrometry (GC-MS).

Experimental

About 40 mg of each sample was diluted in 2 ml of dichloromethane. The sample was then analysed with our SI-DIESEL method using a Finnigan GC-MS instrument. Instrumental conditions are enclosed in Appendix 1. Appendix 2 gives a more detailed description of the method.

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Results and discussion

The results are given in Table 1. The GC-MS instrument was calibrated with sample "6506/12-9S, DST 2", which was made by mixing the C_{10} to C_{19} fractions. To test the long term reproducibility of the GC-MS system, the C_{14} fraction of the above mentioned sample was analysed and compared with previous analysis of the same sample. Since December 1995 a total of 12 parallels have been analysed with an average standard deviation of 3,9 relative % for the groups containing more than 0.1 weight-%. The results are given in Table 2.

Table 1. Composition in weight-% of sample "15/9-19A".

Compound	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}
Paraffins	40,4	40,8	37,7	37,5	37,9
Naphthenes	35,4	34,3	32,4	30,7	29,7
Alkylbenzenes	24,1	21,1	18,3	13,5	10,8
Indanes+Tetralines	0,10	2,89	8,65	12,9	13,5
Naphthalene	0,00	0,89	2,32	0,66	0,13
Alkylnaphthalenes	0,00	0,00	0,64	4,55	6,56
Acenaphthenes+Biphenyles	0,00	0,00	0,00	0,15	1,51
Fluorenes+Acenaphthylenes	0,00	0,00	0,00	0,00	0,00
Phenanthrenes	0,00	0,00	0,00	0,00	0,00
Dibenzothiophenes	0,00	0,00	0,00	0,00	0,00
Compound	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}
Paraffins	34,7	38,3	40,6	38,1	32,5
Naphthenes	31,0	30,2	28,9	31,0	32,9
Alkylbenzenes	9,49	8,62	7,28	4,92	2,05
Indanes+Tetralines	12,4	7,49	4,02	1,72	0,41
Naphthalene	0,00	0,00	0,00	0,00	0,00
Alkylnaphthalenes	8,75	7,57	6,09	4,61	2,72
Acenaphthenes+Biphenyles	3,42	6,70	10,6	14,38	16,1
Fluorenes+Acenaphthylenes	0,25	0,87	1,30	2,08	7,69
Phenanthrenes	0,00	0,06	0,40	1,00	1,73
Dibenzothiophenes	0,00	0,16	0,79	2,09	3,94

Table 2. Composition of the C_{14} fraction of sample "6506/12-9S" in weight-%.

Compound	% s.d.	Average	Feb. 98
Paraffins	2,6	36,3	35,2
Naphthenes	4,5	30,6	31,1
Alkylbenzenes	3,9	5,45	5,50
Indanes+Tetralines	4,9	12,0	13,0
Naphthalene	11,1	0,040	0,030
Alkylnaphthalenes	3,3	12,8	12,3
Acenaphthenes+Biphenyles	4,3	2,68	2,71
Fluorenes+Acenaphthylenes		0,00	0
Phenanthrenes		0,00	0
Dibenzothiophenes		0,00	0
Average (> 0.1 weight-%)	3,9		

Yours sincerely
SINTEF Applied Chemistry

Nina Gjøs
Laboratory manager
Environmental Technology and Analysis

Hilde Drangsholt
Senior engineer

Enclosures:
1. Instrumental conditions
2. Description of the SI-DIESEL method
3. Diskette with the report in Microsoft Word 6.0 format

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Appendix 1. Instrumental conditions

Mass spectrometer:	Finnigan MAT SSQ 700
Gas chromatograph:	Varian 3400
Data system:	DecStation 5000/133
Temperatures	
Column:	30 °C (2 min) - 4 °C/min - 250 °C (15 min.)
Injector:	280 °C
Ion source	150 °C
Carrier Gas:	He
Ionisation:	70 eV
Scan:	35-350, 0.5 sec. pr. scan
Column:	30 m DB-5 MS, 0.25 µm film, 0.25 mm i.d., 12 psi
Injection:	1 µl with a split flow of 50 ml/min

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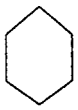
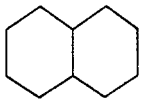
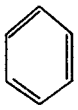
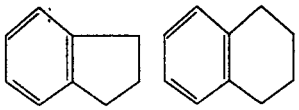
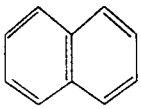
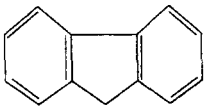
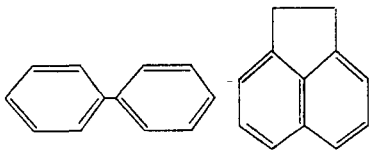
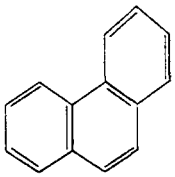
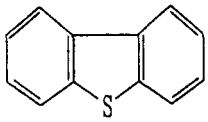
Appendix 2. Description of the SI-DIESEL method

The following compounds are analysed with the SI-DIESEL method:

	Paraffines (C_8 - C_{32})	
	Mono-naphthenes	
	Di-naphthenes	
	Benzenes	C_2 - C_{12}
	Indanes/Tetralines	C_1-C_8/ C_0-C_7
	Naphthalenes	C_0 - C_7
	Fluorenes	C_0 - C_5
	Biphenyles/Acenaphthenes	C_0 - C_6
	Phenanthrenes	C_0 - C_5
	Dibenzothiophenes	C_0 - C_4

The compounds are analysed by GC-MS using regular electron impact ionisation. The areas of the different compounds are determined by integrating the molecular ions within specified retention windows for each compound group. The areas are then multiplied by a correction factor to get the total area of the compound.

The aliphatic compounds are determined by integrating the most intense fragment ions. A matrix calculation is then used to correct for interferences between the aliphatic compounds. There may of course be interferences between different compounds that are not corrected by the software. This is however, minimised by use of specific retention windows for each compound group.

The sum of all groups is normalised to 100 weight-%.

A reference sample is used to measure the response of the different compounds.

Enclosure 4

Viscosity measurements performed by Statoil, F&U:

Method and instrumentation:

A Paar Physica USD (Universal Dynamic Specrometer) 200 reometer with Z1 DIN (double gap) sylinder is used for measurements. The heater/cooler is a LAUND RC6 CP with siliconoil (20 cSt) as medium. Programming of parameters was done by PC with the software US 200 v. 1,80 (Universal Software)