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Title

Wax and hydrocarbon analysis of well 34/10-13 DST 2.

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Key words

Wax, viscosity, asphaltene, hydrocarbon group type, GC-fingerprint.

Abstract

Essential data of the crude oil:

Molecular weight	:	201	g/gmole
Density	:	0.838	g/cc
Weight % C10+	:	80.76	
Wax content	:	7.0/5.2	wt %
Asphaltene content	:	0.4	wt %
Pour point	:	- 3	^{o}C
Wax app. point	:	+ 40-43	^{o}C

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OVERVIEW OF BLOCK 34/10

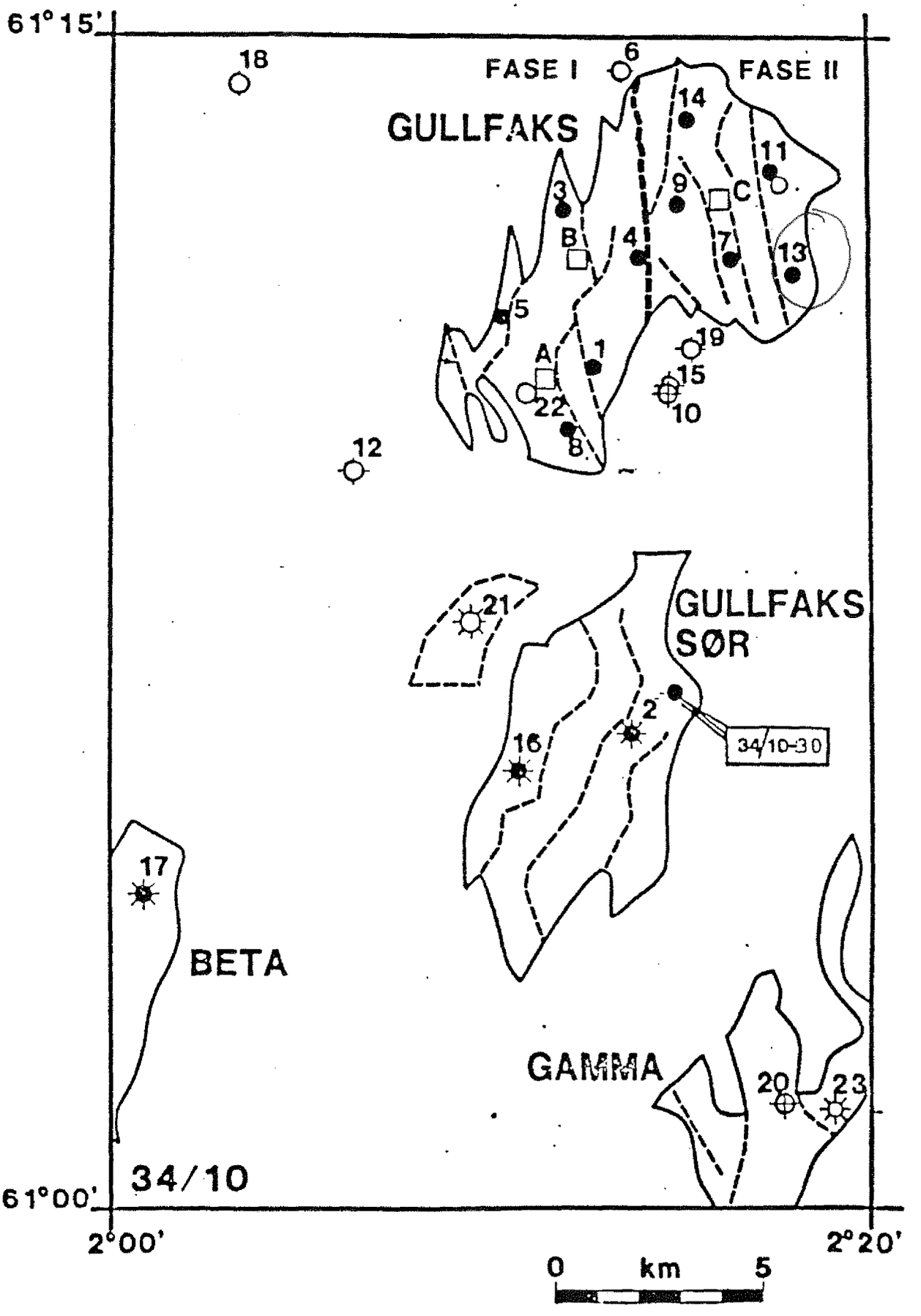

Fig.1

INTRODUCTION

The present report presents the results from chemical and physical characterization of a crude oil sample from well 34/10-13 DST no. 2.

Characterization of the oil includes measurments of wax related properties as pour point, wax appaerance point, viscosity and wax content, and determination of hydrocarbon group types and asphaltenes. In addition, some concentration ratios and indices, primarily of geochemical interest, are calculated.

The analyses were performed on a stabilized crude oil sample which had been obtained by flashing a separator oil sample to ambient conditions.

Some data of the sample:

Well	:	34/10-13
Test	:	DST 2
Structure	:	Gullfaks
Formation	:	Statfjord
Depth (m RKB)	:	2003 - 2009
Date of sampling	:	24.12.81
Time of sampling	:	22.35
Bottle no.	:	K-16251/5 (Separator sample)

TABLES

Table 1. Summary of essential data of crude oil 34/10-13 DST 2.

	Crude oil	C10+	C20+
Weight percent of oil	100	80.76 (a)	44.90 (a)
Molecular weight (g/gmole)	201	269	439
Density (g/cc)	0.838	0.868	0.913
Wax content (wt%)			
Not purified	7.0		
Purified	5.2		
Pentane insolubles (wt%) (asphaltenes)	0.4	0.5	0.9
Saturates (wt%)		67.4	
Aromatics (wt%)		30.0	
Polars (wt%)		2.1	
Pristane/phytane (b)	1.91		
Pristane/n-C17 (b)	0.75		
Phytane/n-C18 (b)	0.50		
n-C17/n-C27 (b)	3.95		
CPI 1 *	1.15		
CPI 2 *	1.02		
MPI 1 *	0.60		
MPI 2 *	0.65		
Pour point (°C)	- 3		
Wax app. point (°C)	+ 40-43		
Dynamic viscosity (mPa s)			
($298\ s^{-1}$) 5 °C	12.2		
10 °C	8.6		
20 °C	5.1		
30 °C	3.5		
40 °C	2.5		

(a) Calculated from GC.

(b) Area percent ratio from paraffin-naphtene chromatogram.

* For definition of Carbon Preference Indices and Methyl Phenanthrene Indices, see appendix C.

Table 2. Dynamic viscosity (mPa s) vs. shear rate and temperature of crude oil 34/10-13 DST 2.

Shear rate (s^{-1})	5°C	10°C	20°C	30°C	40°C
102	12.3	7.7	-	-	-
145	12.4	8.1	4.5	-	-
209	12.4	8.5	4.7	3.3	-
298	12.2	8.6	5.1	3.5	2.5
427	12.1	8.7	5.2	3.7	2.7
611	12.0	8.7	5.3	3.8	2.8
875	11.9	8.7	5.3	3.8	2.9
1252	11.5	8.6	5.3	3.8	2.9
1793	11.2	8.5	5.3	3.9	3.0

The viscosity was measured with increasing shear rate with a shear duration of 20 seconds at each step.

Table 3. Characteristic ratios of some aromatics, n-alkanes and isoprenoids of crude oil 34/10-13 DST 2.

Pristane/phytane	1.91
Pristane/n-C17	0.75
Phytane/n-C18	0.50
n-C17/n-C27	3.95
CPI 1 *	1.15
CPI 2 *	1.02
Cyclohexane / methylcyclopentane	1.58
Toluene / n-heptane	0.81
n-heptane / methylcyclohexane	0.69
2-MN / 1-MN	1.21
2,6+2,7- / 1,4+1,5+2,3-DMN	1.03
Biphenyl / 1+2-EN	1.13
Biphenyl / 3-M-biphenyl	0.83
MPI 1 *	0.60
MPI 2 *	0.65

* See definition of Carbon Preference Indices and Methyl Phenanthrene Indices in appendix C.

N = naphtalene
M = methyl-
DM= dimethyl-

Table 4. Distribution of n-alkanes in crude oil 34/10-13 DST 2 (weight percent of whole oil).

n-Cn		Weight percent
6	*	1.02
7	*	1.13
8	*	1.23
9	*	1.12
10	*	0.87
11	*	0.85
12		0.72
13		0.70
14		0.64
15		0.62
16		0.54
17		0.51
18		0.41
19		0.37
20		0.33
21		0.28
22		0.26
23		0.23
24		0.21
25		0.21
26		0.15
27		0.13
28		0.11
29		0.10
30		0.07
Sum		12.81

* These compounds are quantified in the whole oil chromatogram. The rest are taken from the C10+ paraffin-naphtene chromatogram. n-C12 to n-C30 are adjusted, so that n-C12 is exactly equal from the two sources.

FIGURES

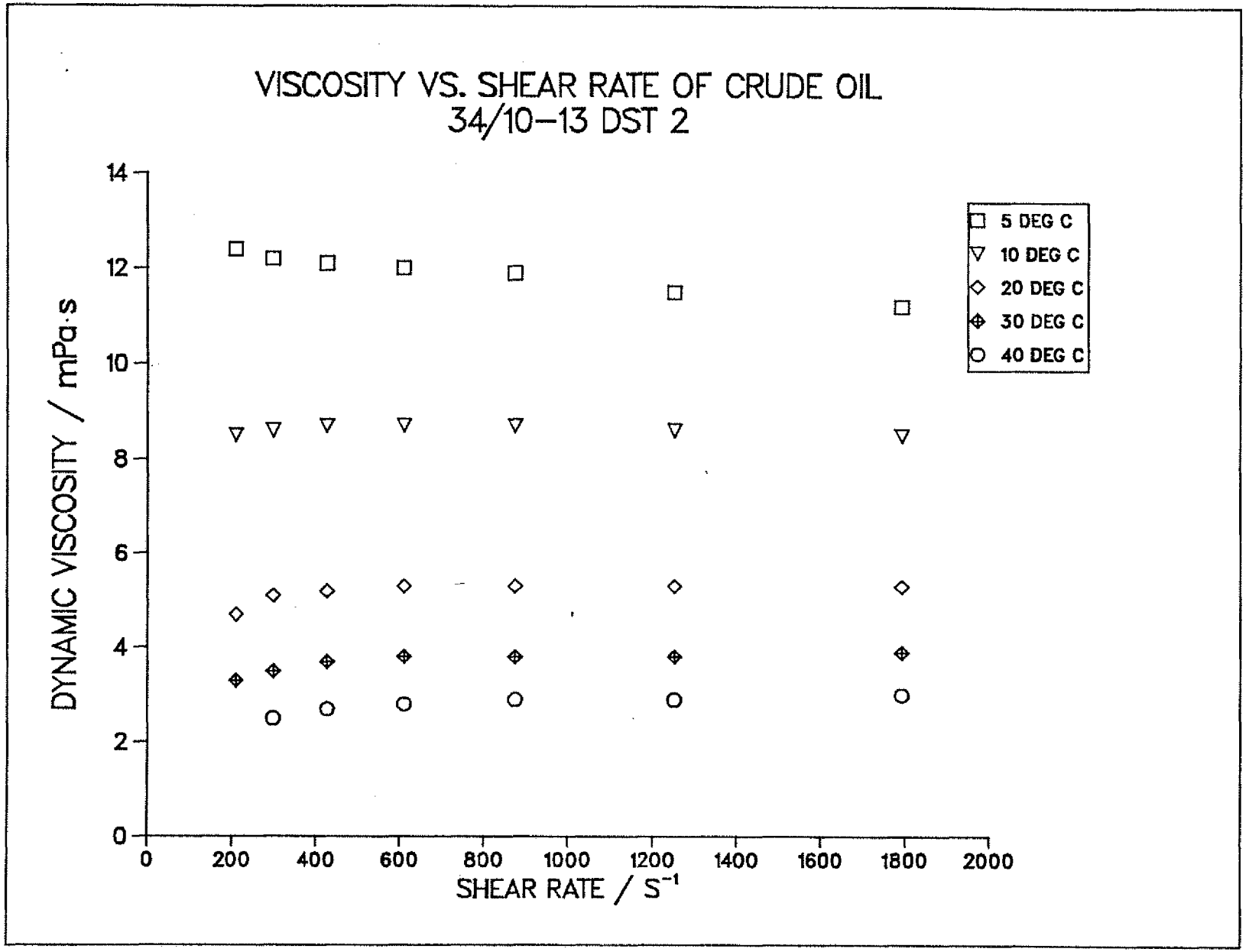
VISCOSITY VS. SHEAR RATE OF CRUDE OIL
34/10-13 DST 2
DYNAMIC VISCOSITY / mPa·s
SHEAR RATE / S⁻¹
0
2
4
6
8
10
12
14
0
200
400
600
800
1000
1200
1400
1600
1800
2000
5 DEG C
10 DEG C
20 DEG C
30 DEG C
40 DEG C

Fig.2

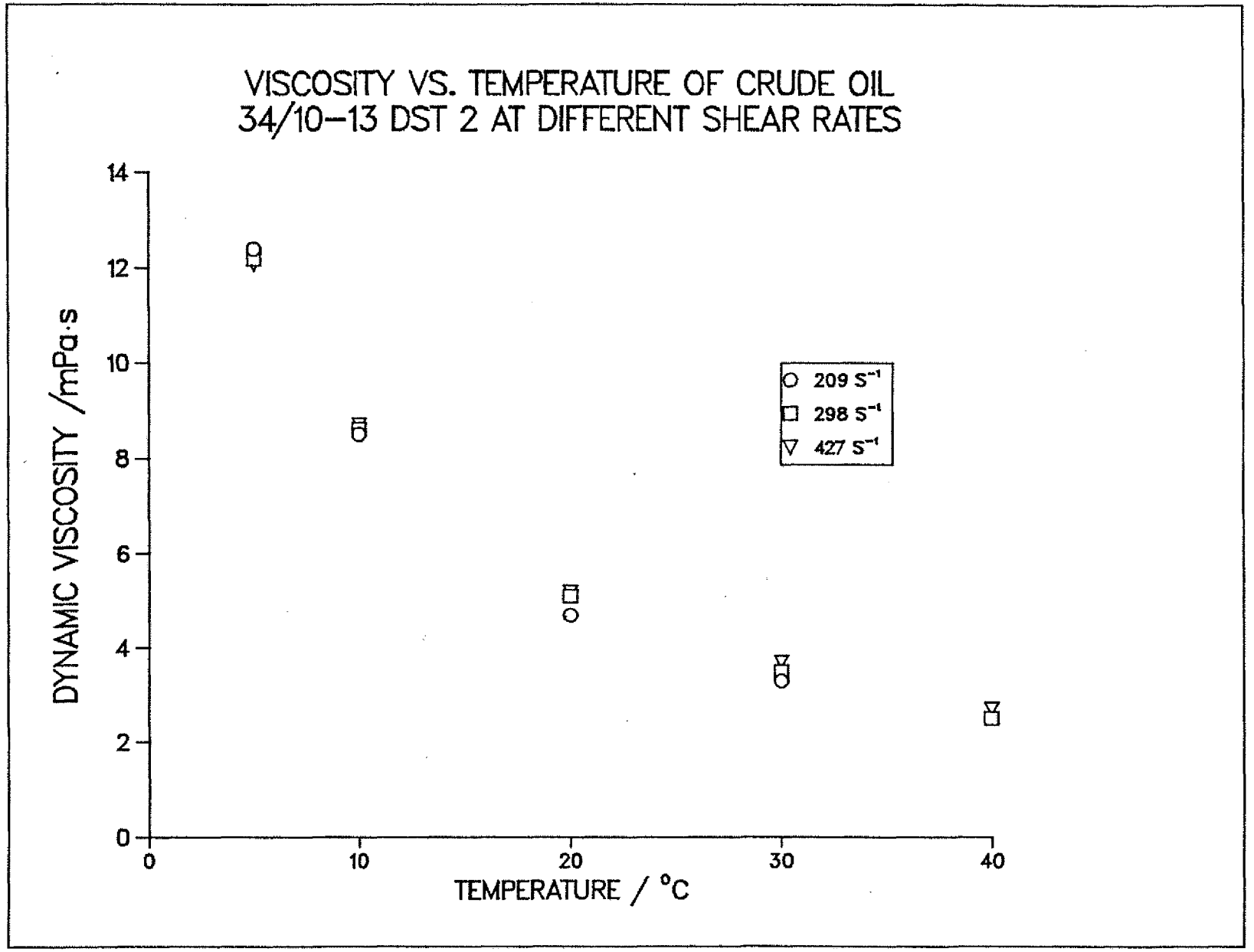
VISCOSITY VS. TEMPERATURE OF CRUDE OIL
34/10–13 DST 2 AT DIFFERENT SHEAR RATES
DYNAMIC VISCOSITY /mPa·s
TEMPERATURE / °C
209 S⁻¹
298 S⁻¹
427 S⁻¹
0
2
4
6
8
10
12
14
0
10
20
30
40

Fig.3

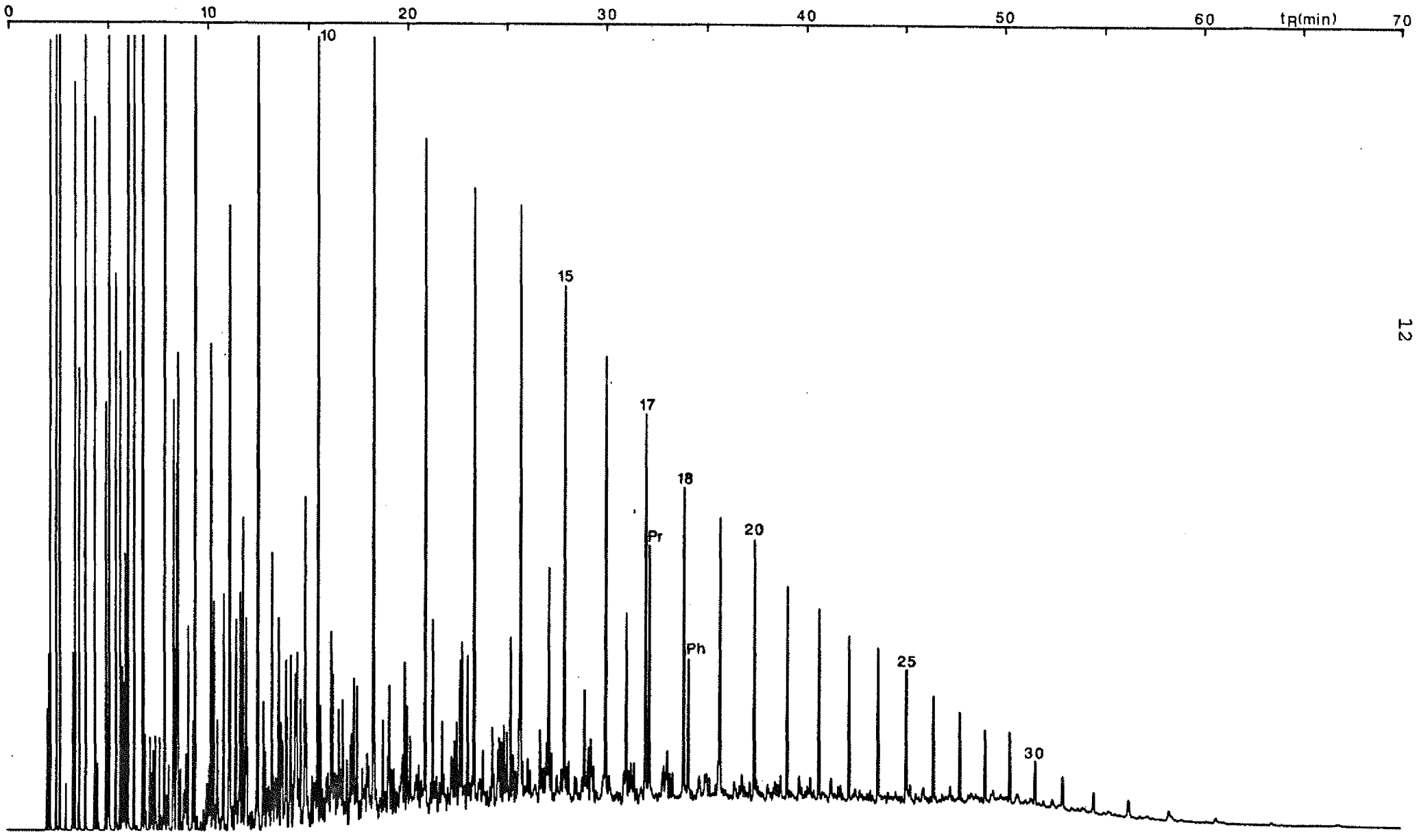
A13201 100mV
CRUDE OIL 34/10-13 DST2
0
10
20
30
40
50
60
tR(min)
70
10
15
17
18
20
25
30
Pr
Ph

Fig.4

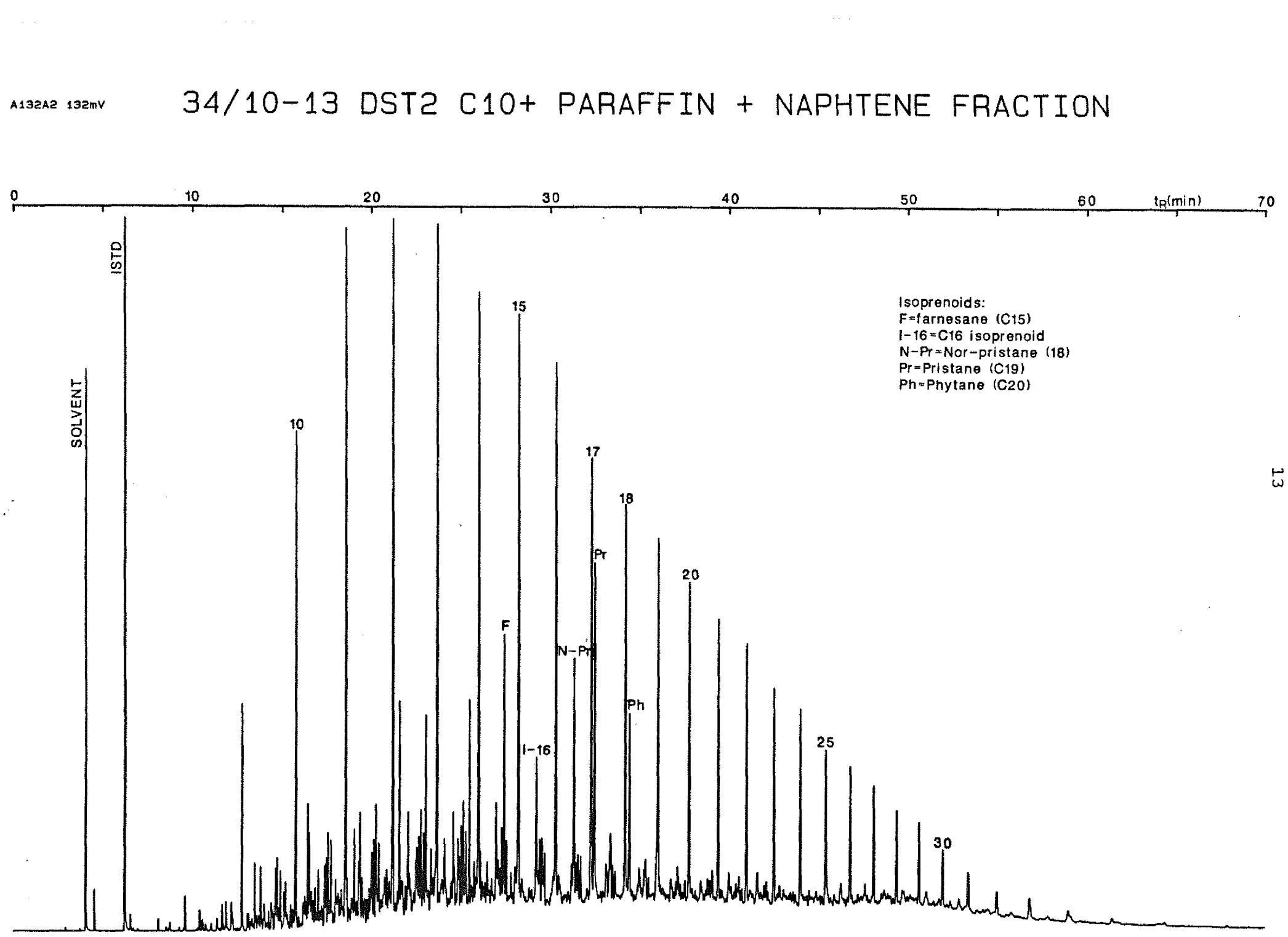
A132A2 132mV
34/10-13 DST2 C10+ PARAFFIN + NAPHTENE FRACTION
0
10
20
30
40
50
60
tR(min)
70
SOLVENT
ISTD
10
15
17
18
Pr
20
F
N-Pr
Ph
I-16
25
30
Isoprenoids:
F=farnesane (C15)
I-16=C16 isoprenoid
N-Pr=Nor-pristane (18)
Pr=Pristane (C19)
Ph=Phytane (C20)

Fig.5

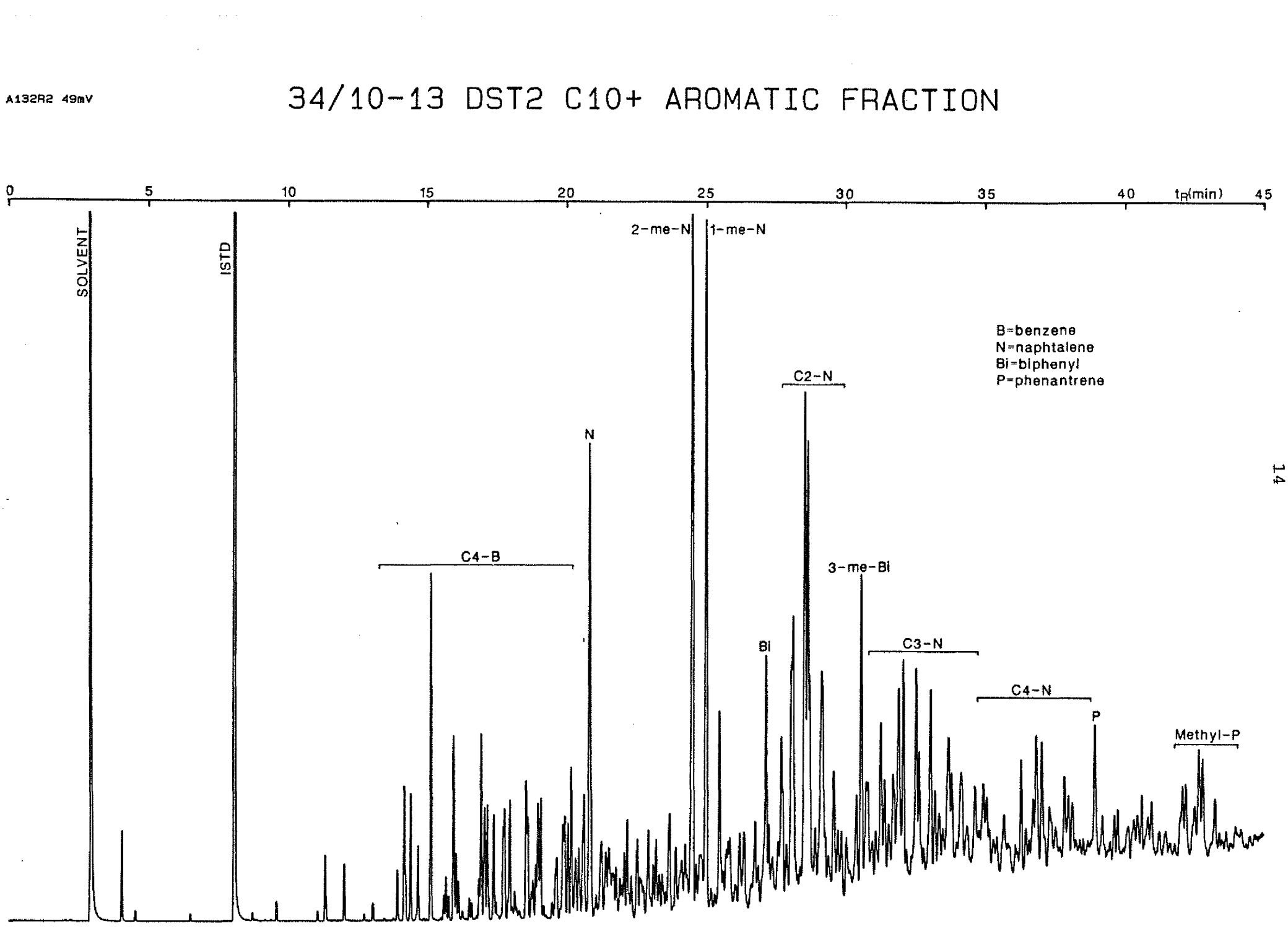
A132R2 49mV
34/10-13 DST2 C10+ AROMATIC FRACTION
0
5
10
15
20
25
30
35
40
tR(min)
45
SOLVENT
ISTD
2-me-N
1-me-N
N
C4-B
C2-N
3-me-Bi
Bi
C3-N
C4-N
P
Methyl-P
B=benzene
N=naphtalene
Bi=biphenyl
P=phenantrene

Fig.6

APPENDIX

APPENDIX A

Table A.1. Detailed composition of light end of crude oil 34/10-13 DST 2 (weight percent of whole oil).

Component	Weight%	Molecular weight	Density
C1	0.00	16.0	0.260
C2	0.00	30.1	0.358
C3	0.04	44.1	0.508
i-C4	0.07	58.1	0.563
n-C4	0.32	58.1	0.585
2,2-DM-C3	0.00	72.2	0.597
i-C5	0.45	72.2	0.625
n-C5	0.75	72.2	0.631
2,2-DMC4	0.03	86.2	0.654
Cy-C5	0.12	70.1	0.750
2,3-DM-C4	0.06	86.2	0.666
2-M-C5	0.48	86.2	0.658
3-M-C5	0.31	86.2	0.669
n-C6	1.02	86.2	0.664
M-Cy-C5	0.57	86.2	0.753
2,4-DM-C5	0.05	100.2	0.677
Benzene	0.33	78.1	0.884
Cy-C6	0.90	84.2	0.783
2-M-C6	0.45	100.2	0.683
1,1-DM-Cy-C5	0.00	98.2	0.759
1-cis,2-DM-Cy-C5	0.09	98.2	0.777
3-M-C6	0.40	100.2	0.692
1-cis,3-DM-Cy-C5	0.14	98.2	0.749
1-trans,3-DM-Cy-C5	0.13	98.2	0.753
1-trans,2-DM-Cy-C5	0.27	98.2	0.756
n-C7	1.13	100.2	0.688
Unspecified C7	0.02	100.2	0.680
M-Cy-C6	1.64	98.2	0.774
1,1,3-TM-Cy-C5	0.10	112.2	0.753
E-Cy-C5	0.08	98.2	0.753
2,2,3-TM-Cy-C5	0.05	114.2	0.720
2,5-DM-C6	0.07	114.2	0.698
2,4-DM-C6	0.09	114.2	0.705
3,3-DM-C6	0.02	114.2	0.714
1-trans,2-cis-3-TM-Cy-C5	0.08	112.2	0.758
Toluene	0.91	92.1	0.871
1,1,2-TM-Cy-C5	0.09	112.2	0.777

table A.1 cont.

Component	Weight%	Molecular weight	Density
2,3-DM-C6	0.01	114.2	0.716
2-M-C7	0.43	114.2	0.702
3-M-C7	0.00	114.2	0.710
1-cis-3-DM-Cy-C6	0.67	112.2	0.770
1-trans-4-DM-Cy-C6	0.15	112.2	0.767
Unspecified naphtene	0.06	112.2	0.770
Unspecified naphtene	0.04	112.2	0.770
Unspecified naphtene	0.03	112.2	0.770
DM-Cy-C6	0.08	112.2	0.770
1-trans-2-DM-Cy-C6	0.20	112.2	0.780
n-C8	1.23	114.2	0.707
Unspecified C8	0.20	114.2	0.700
Unspecified naphtene	0.02	126.2	0.790
2,2-DM-C7	0.02	128.3	0.714
2,4-DM-C7	0.00	128.3	0.719
1-cis-2-DM-Cy-C6	0.11	112.2	0.800
E-Cy-C6 + 1,1,3-TM-Cy-C6	0.53	118.0	0.790
Unspecified naphtene	0.15	126.2	0.790
3,5-DM-C7	0.13	128.3	0.726
2,5-DM-C7	0.03	128.3	0.721
Ethylbenzene	0.20	106.2	0.871
Unspecified naphtene	0.08	126.2	0.790
Meta + para-xylene	0.81	106.2	0.866
4-M-C8	0.15	128.3	0.724
2-M-C8	0.20	128.3	0.717
Unspecified naphtene	0.03	126.2	0.790
Unspecified naphtene	0.24	126.2	0.790
Unspecified naphtene	0.00	126.2	0.790
Ortho-xylene	0.32	106.2	0.884
3-M-C8	0.07	128.3	0.724
1-M,3-E-Cy-C6	0.17	126.2	0.800
1-M,4-E-Cy-C6	0.12	126.2	0.790
Unspecified naphtene	0.03	126.2	0.790
n-C9	1.12	128.3	0.721
Unspecified C9	0.39	128.3	0.720

Explanation of the abbreviations:

Cy-	Cyclo-
D	Di-
E	Ethyl-
M	Methyl-
T	Tri-

APPENDIX B

A brief description of the analytical methods.

1.Gas chromatograms of whole oils, aromatics and paraffines/ naphtenes are recorded using a Cp Sil 5 CB column (25 mm x 0.23 mm i.d., 0.13 um filmthickness) and FI-detector. The following temperature programs are used:

A. Whole oils/paraffines-naphtenes:

10 °C 2 min
6 °C/min to 300 °C

B. Aromatics:

10 °C 2 min
6 °C/min to 85 °C
4 °C/min to 240 °C
15 °C/min to 300 °C

Injector(split): 300 °C
Detector : 300 °C

2.Molecular weights are determined by freezing point depression of benzene (Cryette, Precision Instr.), except for C4 -C9 which are calculated from GC-composition. Precision of the method is about 1.5 % (RSD) for residues and about 1 % for lower fractions.

3.Densities of liquid fractions are measured using a Paar DMA 62 frequency densiometer, thermostatted at 15 °C. Densities of the C4 - C9 fractions are calculated from the GC-compositions.
Precision of the method is +/- 0.0001 g/cc.

4.Wax content is determined by a modified UOP method 46-64, described by Burger et al. (Journ. Petr. Tech., June 1981, 1075), the acetone precipitation technique. The wax is precipitated with acetone at -25 °C and filtrated. The precipitate is purified by elution through a short silica cartridge.

5.Pour point is determined according to ASTM D-97 (1980).

6.Wax appearance point is determined by polarization micro-scopy (due to optical anisotropy wax crystals have the ability to rotate polarized light). The sample is cooled slowly after first being heated to 70 °C.

7.Dynamic viscosity is measured with a Contraves Rheomat 115 rotational viscometer. Viscosity is measured at 5, 10, 20, 30 40 and 50 °C at different shear rates. Reported flow curves represent a series of measurements at increasing shear rate and a shear duration of 20 seconds at each shear rate.

8.Pentane insolubles (asphaltenes) are precipitated with pentane (1:40 vol:vol) and filtrated through a 0.45 um filter.

9.Hydrocarbon group type analysis of C10+ (and C20+) fractions are performed by preparative liquid chromatography using a combination of cyanosilane column to trap polar compounds (resins) and a silica column to separate aromatics from paraf-fines/naphtenes (saturates). The columns are connected in series. The saturates are eluted first with hexane. Both columns are then backflushed with hexane to elute the aromatics. At last, the strongly retained, polar material is backflushed from the cyano-column with tetrahydrofurane.

The solvent is removed by vacuum evaporation, and the fractions quantified by weighing. Residual hexane is determined by GC with internal standard, and corrected for.

Further fractionation of the aromatics according to number of aromatic carbons, may be done on an aminosilane column eluted with hexane.

APPENDIX C

Definition of Carbon Preference Indices:

$$CPI\ 1 = 1/2\ \ (C25 + C27 + C29 + C31\ /\ C24 + C26 + C28 + C30) + (C25 + C27 + C29 + C31\ /\ C26 + C28 + C30 + C32)$$

$$CPI\ 2 = 2 \times (C27\ /\ C26 + C28)$$

Definition of Methyl Phenanthrene Indices:

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

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