STATOIL

Well: 15/9–19A

DST 2A

PVT ANALYSIS OF SINGLE PHASE SAMPLE

REPORT NO.: STAT550B

MAY 1998

Oilphase

LABORATORY REPORT

TITLE : 15/9-19A, PVT ANALYSIS OF SINGLE PHASE SAMPLE

Client Name and Address	Date Sampled	28.10.1997
STATOIL	Date of arrival	19.11.97
P. box 300	Date Analysed	Nov.-Dec. 1997
4001 STAVANGER	Date Reported	28.05.1998
Attn.: Tore Tjomsland	Oilphase Reference	STAT550B

Client Contact Person	Tore Tjomsland
Contract / Order Reference	Contract no. VMS 14435/
Number of Samples	1
Sample Type	Single Phase Sample
Sample Identification	20770
Sampling Location	-
Sampling Procedure	-
Condition of Sample on arrival	OK

Analysis Results
We refer to attached report for analysis results.

Analysed by subcontractors	Method	Subcontractor

Comments
The analyses are not accredited analyses.

We hereby confirm that the results obtained refer to the samples provided. This report shall not be copied in part without prior approval from Oilphase. If you have any questions regarding this report, please do not hesitate to contact us. If not otherwise stated all analyses on this report are accredited.

Stavanger, 28th May 1998

Egil Linjord
Chief Analyst

Erik Løe
Lab. engineer

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1. INTRODUCTION

This report contains the results from the PVT analyses on the fluid from Well 15/9-19A. The analyses have been performed in agreement with the scope of work given by Statoil with reference to the contract no.: VMS 14435/

Company contact person: Tore Tjomsland
Oilphase contact person: Erik Løe

Stavanger, 28.05.98

2. SCOPE OF WORK

The following analyses have been performed on the fluid from well 15/9-19A:

- Constant mass expansion of reservoir fluid at reservoir temperature.
- Single stage flash including the compositional analysis to C_{10}+.

The analyses were performed on the reservoir fluid at conditions given by Statoil.

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3. SUMMARY

Reservoir Fluid Study
Well: 15/9-19A
Reservoir fluid sample
Bottle no. : 20770
May, 1998

This report presents the results of a PVT-study of a reservoir fluid from well 15/9-19A.

Single-stage flash and constant mass expansion were determined on the fluid at 110°C (reservoir temp.).

Main results:

Bubble point pressure	:	235.5	bar
Compressibility at bubble point pressure	:	$1.72 \cdot 10^{-4}$	bar^{-1}

From single-stage flash:

Gas/oil ratio	:	111.8	Sm^3/Sm^3
B_o at bubble point pressure	:	1.388	m^3/Sm^3
Density of oil at standard conditions	:	900.5	kg/Sm^3
Density of oil at bubble point pressure	:	733.4	kg/m^3

STANDARD CONDITIONS:	for gas volume	:	15°C and 1.01325 bar absolute
	for oil volume	:	15°C and atmospheric pressure

All the pressures are expressed in bar absolute = bar

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4. SAMPLE

The reservoir fluid sample from 15/9-19A Test 2A for the PVT analysis was supplied by Statoil.

The sample was a single phase sample and no quality check was performed.

Field	: Sleipner	
Formation	: Hugin	
Well	: 15/9-19A	
Test	: 2A	
Interval tested, perforations	: 3885.5 - 3888.5 m MD RKB, 3074.9 - 3077.5 m TVD MSL	
Reservoir fluid	: Oil	
Static bottom hole conditions		
Reservoir pressure	: (322)	bar 336.5 ba (initial)
Reservoir temperature	: 111	°C
Date of sampling	: 28.10.97	
Time of sampling	: 22:22 - 22:44	
Type of sample	: Single Phase oil sample	
Oil bottle	: 20770	
Gas bottle	: -	
Separator conditions		
Separator pressure	: -	bar
Separator temperature	: -	°C
Dynamic bottom hole conditions		
Flowing pressure	: -	bar
Flowing temperature	: -	°C
Flow rates		
Separator gas rate	: -	Sm^3/D
Separator oil rate	: -	m^3/D
Gas-oil ratio	: -	Sm^3/m^3
Gas gravity	: -	
z-factor	: -	
From separator gas composition		
Gas gravity	: -	
z-factor	: -	
Corrected gas-oil ratio	: -	Sm^3/m^3

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5. COMMENTS

Sample:

The sample for the PVT analysis was transferred from a Single Phase sampler to a single phase storage bottle by Maritime Well Services AS.

Single Phase Sampler	:	Xact Single Phase, SPS 073
Storage bottle no.	:	20770

After the transfer of the sample to the PVT cell the sample was kept in single phase conditions for further analysis.

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6. SINGLE STAGE FLASH OF RESERVOIR FLUID

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6.1 FLASH OF RESERVOIR FLUID TO STOCK TANK CONDITIONS.

Flash conditions: 351.5 bar and 110.°C to atmosphere and 28°C.

Bottle no.: 20770

Gas oil ratio	: 111.8	Sm^3/Sm^3	1)
B_o at 351.5 bar	: 1.362	m^3/Sm^3	2)
B_o at bubble point pressure	: 1.388	m^3/Sm^3	3)
Density of oil at 15°C	: 900.5	kg/Sm^3	
Density of fluid at bubble point pressure at Pres 336.5 bar	: 733.4 745.4	kg/m^3	
Molecular weight of dead oil (measured)	: 257		
Gas gravity (air=1)	: 0.856		
Molecular weight of C_{7+} (calculated)	: 283		4)
Density of C_{7+} (calculated)	: 914	kg/Sm^3	4)
Molecular weight of C_{10+} (calculated)	: 335		4)
Density of C_{10+} (calculated)	: 932	kg/Sm^3	4)

1) Standard m^3 gas per Sm^3 stock tank oil.
2) m^3 of separator liquid at 351.5 bar per Sm^3 stock tank oil
3) m^3 of separator liquid at bubble point per Sm^3 stock tank oil.
4) Stock tank oil.

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6.2 FLASH OF RESERVOIR FLUID TO STOCK TANK CONDITIONS

MOLECULAR COMPOSITION AND PNA DISTRIBUTION

Sample from bottle no.: 20770, Chamber Xact SPS 073

Stock tank gas

Component	Wt%	mol%	molwt.	LNG 1)
Nitrogen	0.93	0.82		
Carbon dioxide	4.99	2.81		
Methane	45.14	69.79		
Ethane	12.17	10.04		
Propane	15.24	8.57		314.9
iso-Butane	2.43	1.04		45.3
n-Butane	8.07	3.45		145.0
iso-Pentane	2.59	0.89		43.5
n-Pentane	3.42	1.18		56.9
Hexanes	2.54	0.75	83.8	40.2
P	2.22	0.64		
N	0.32	0.11		
A	0.00	0.00		
Heptanes	1.91	0.53	89.1	29.1
P	0.60	0.15		
N	0.99	0.28		
A	0.32	0.10		
Octanes	0.44	0.10	105.7	6.5
Nonanes	0.03	0.01	119.2	0.4
Decanes plus	0.10	0.02	156	1.5
Sum	100.00	100.00		683.3
Average molecular weight :			24.81	

1) Liquified natural gas as m^3 liquid/10^6 Sm^3 gas

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6.3 FLASH OF RESERVOIR FLUID TO STOCK TANK CONDITIONS

MOLECULAR COMPOSITION AND PNA DISTRIBUTION

Sample from bottle no.: 20770, Chamber Xact SPS 073.

Stock tank oil

Component	Wt%	mol%	molwt.	density kg/m³
Nitrogen	-	-		
Carbon dioxide	-	-		
Methane	-	-		
Ethane	0.03	0.23		
Propane	0.22	1.28		
iso-Butane	0.10	0.43		
n-Butane	0.46	2.04		
iso-Pentane	0.37	1.30		
n-Pentane	0.65	2.33		
Hexanes	1.42	4.32	84.5	669
P	1.29	3.86		
N	0.13	0.46		
A	0.00	0.00		
Heptanes	2.62	7.38	91.4	739
P	1.24	3.23		
N	1.01	2.93		
A	0.37	1.22		
Octanes	2.97	7.23	105.7	759
P	1.24	2.76		
N	1.19	2.96		
A	0.54	1.51		
Nonanes	2.50	5.39	119.2	772
P	1.24	2.48		
N	0.62	1.37		
A	0.64	1.54		
Decanes plus	88.66	68.07	335	932
Sum	100.00	100.00		
Average molecular weight :			257	

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6.4 MATHEMATICALLY RECOMBINED RESERVOIR FLUID

MOLECULAR COMPOSITION AND PNA DISTRIBUTION

Sample from bottle no.: 20770, Chamber Xact SPS 073

Component	Wt%	mol%	molwt.
Nitrogen	0.11	0.47	
Carbon dioxide	0.58	1.62	
Methane	5.20	40.12	
Ethane	1.43	5.87	
Propane	1.95	5.47	
iso-Butane	0.37	0.78	
n-Butane	1.34	2.85	
iso-Pentane	0.62	1.07	
n-Pentane	0.97	1.67	
Hexanes	1.54	2.27	84.3
P	1.39	2.01	
N	0.15	0.26	
A	0.00	0.00	
Heptanes	2.54	3.44	90.9
P	1.18	1.45	
N	1.00	1.41	
A	0.36	0.58	
Octanes	2.67	3.13	105.7
P	1.10	1.20	
N	1.08	1.27	
A	0.49	0.66	
Nonanes	2.21	2.30	119.2
P	1.10	1.06	
N	0.55	0.58	
A	0.56	0.66	
Decanes plus	78.47	28.94	335
Sum	100.00	100.00	
Average molecular weight :			124

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7. CONSTANT MASS EXPANSION OF RESERVOIR FLUID

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7.1 CONSTANT MASS EXPANSION OF RESERVOIR FLUID

AT 110 °C

SAMPLE: Bottle no. 20770 (from Xact SPS 073), depth 3748 m MD RKB

Pressure bar	Relative volume V/V_{BP}	Isothermal compressibility bar^{-1}	"Y"
451.6	0.9683	$1.26 \cdot 10^{-4}$	
351.6 336.5	0.9817 0.9838	$1.48 \cdot 10^{-4}$	
325.8	0.9854	$1.53 \cdot 10^{-4}$	
300.8	0.9893	$1.58 \cdot 10^{-4}$	
273.6	0.9936	$1.64 \cdot 10^{-4}$	
250.8	0.9974	$1.69 \cdot 10^{-4}$	
235.5 (P_{BP})	1.0000	$1.72 \cdot 10^{-4}$	
224.8	1.0110		4.337
203.9	1.0374		4.139
175.2	1.0903		3.813
150.0	1.1598		3.566
125.4	1.2650		3.313
102.3	1.4200		3.100
82.3	1.6395		2.911
68.8	1.8699		2.785
59.2	2.0984		2.711
52.1	2.3300		2.647

Best fit V equation above bubble point :

$$V_{rel} = 1.0468 - 2.258 \cdot 10^{-4} P + 1.150 \cdot 10^{-7} P^2$$

Best fit Y equation :

$$Y = 2.110 + 0.983 \cdot 10^{-2} P$$

Constant mass expansion, see fig 1 and 2.

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8. FIGURES

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Fig. 1

PRESSURE - VOLUME RELATION OF RESERVOIR FLUID AT 110 °C AND CONSTANT MASS

P_b= 235.5 bar

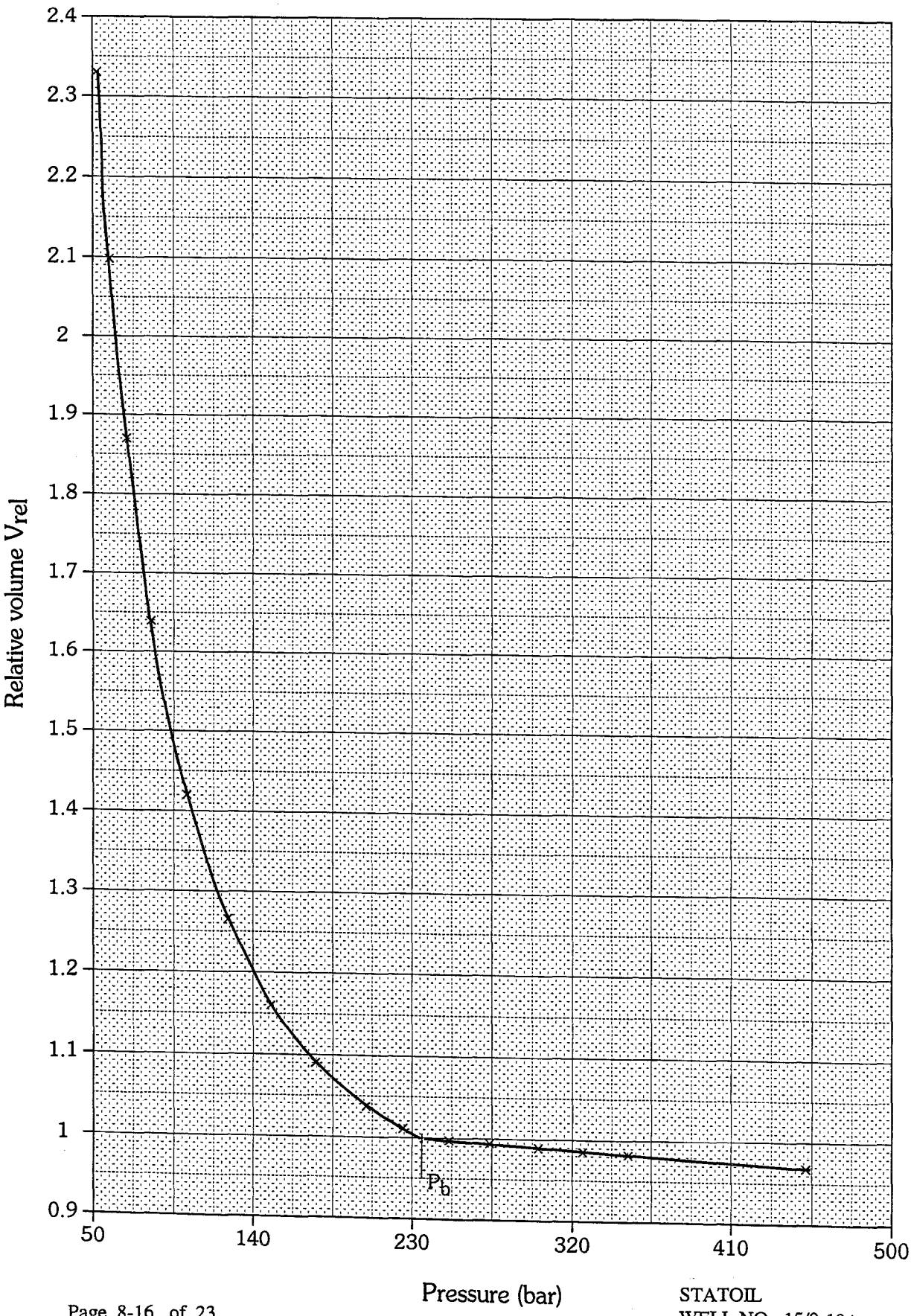

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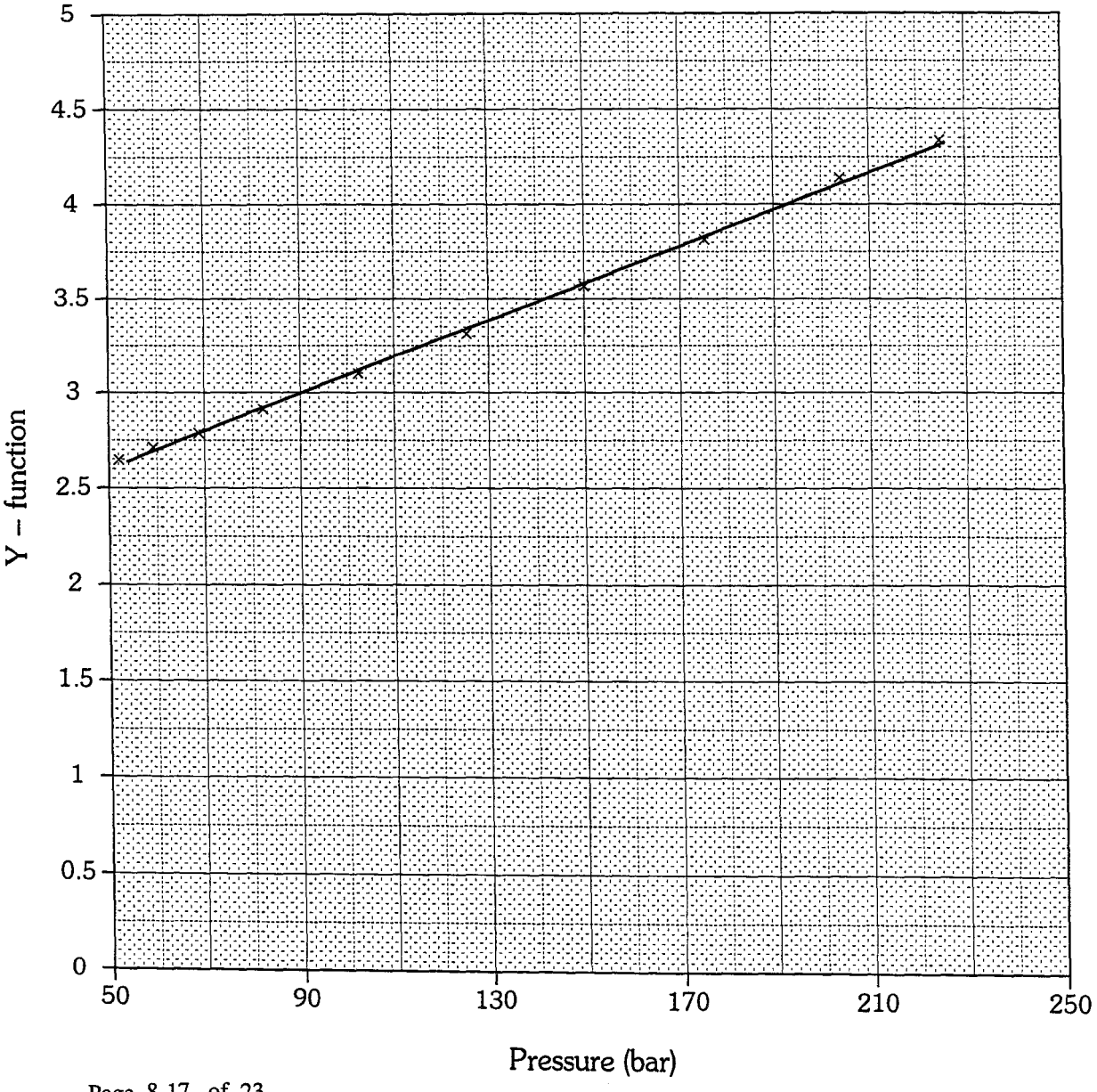
Fig. 2

PRESSURE - VOLUME RELATION OF RESERVOIR FLUID AT 110 °C AND CONSTANT MASS

Y - function



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9. LABORATORY PROCEDURES

PVT-analysis

Constant mass expansion of reservoir fluid was performed in a Ruska PVT cell. Single stage flash of reservoir fluid to 20°C and atmospheric pressure was performed in a glass Flash Separator. Gas volumes were measured by a RUSKA Gasometer. Gas samples for analysis were collected in a gas sampling tube (150-250 ml) connected between the separator and the gasometer.

Accuracy:

Temperature measurements	:	+/- 0.5	°C
Pressure measurements	:	+/- 1	bar

Repeatability:

Gas oil ratio	:	+/- 1	%
B_o factor	:	+/- 1.5	%
Gas volumes	:	+/- 1	%
Oil volumes	:	+/- 1	%

Gas analysis

Gas analysis up to and including nonanes was carried out by a HP 6890 Gaschromatograph. First the light gases including ethane were separated from the heavier hydrocarbons on a 35% DC-200 column (4'x1/8", 80-100 mesh). The light gases, O_2, N_2 and methane were separated on a molecular sieve column (10'x1/8", 13x45-60). CO_2 and ethane were separated on a Porapak column (6'x1/8", 80-100). Carrier gas is helium.

The analysis was carried out isothermally at 36°C. The detection was done by a TCD at 250°C.

The heavier hydrocarbons were backflushed from the DC-200 column and separated on a liquid phase DB-1 fused silica capillary column (50m x 0.322 mm, 1.0 micro filmthickness, starting at a temperature of 36°C. Final column temperature was 170°C. The detection is done by a FID at 300°C. Carrier gas is helium.

The guidelines for the performance of the gas analysis is ASTM D 1945.

The system is calibrated with a calibration gas containing hydrocarbons from methane through hexane, nitrogen and carbondioxide.

Fraction C6 and C7 is analysed in details with the calculations of PNA distribution.

Oil analysis to C10+

The oil hydrocarbons up to and including nonanes were separated in a fused silica capillary column, Hewlett Packard PONA column 50m, 0.50 micron filmthickness. Stationary phase: crosslinked methyl silicon. The gaschromatograph is HP 6880 GC. Temperature is programmed from 35°C to 130°C. The detection is done by a FID at 300°C. Carrier gas is helium.
For the calibration a PNA standard is used.
Iso-octane is used as an internal standard for the quantification. The molecular weights and the densities on the fractions from C6 to C10+ are calculated from the detailed composition.

Density

Density of stock tank oil is determined at 15°C with an AP Paar Density meter, calibrated with dry air and distilled water before each measurement.

Accuracy for the analysis: +/- 0.5 kg/m³.

The density of the saturated oil was calculated on basis of 1 m³ stock tank oil with addition of the evolved gas.

The formula is:

$$\rho \text{ sat. oil} = \frac{\text{Wt, oil + Wt, gas}}{\text{Volume, sat. oil}} = (\rho \text{ st.t.} + GOR \cdot \gamma gas \cdot \rho \text{ air})/B_o$$

Molecular weight

Molecular weight was determined by freezing point depression of benzene with a Roebling Automatic Kryometer.

Accuracy for the analysis: +/- 1%.

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NOMENCLATURE AND DEFINITIONS

General

Description	Symbol	Unit
Temperature	t	°C
Abs. temperature	T	°K
Volume	V	m^3
Pressure	P	bar = absolute pressure
Density	ρ	kg/m^3
Gas gravity	γ	-
Isothermal compressibility		bar^{-1}
Viscosity	μ	mPa · s
Thermal expansion	-	$°C^{-1}$
Heating value	H	kJ/Sm^3
Compressibility factor	z	-
Molar mass	M	-
Number of mole	n	-
Universal gas constant	R	$cm^3 \cdot bar/g\ mol \cdot K$

P_{BP} : Bubblepoint pressure (barg or bara)

B_0 : Oil formation volume factor
Volume of reservoir oil at P and t/Volume of stock tank oil (STO) (m^3/Sm^3)

Vrel : Relative volume

GOR : Gas oil ratio.
Standard volume of gas/volume of STO (Sm^3/m^3), (Sm^3/Sm^3)

LNG : Liquefied natural gas.
Calculated liquid volume of the gas component as liquid (m^3 liquid/10^6 Sm^3 gas)

PNA : Paraffines, Napthenes, Aromatics

Rs : Solution gas oil ratio.
Gas in solution at P and t (Sm^3/STO (m^3))

Bg : Gas formation volume factor.
Volume of gas at P and t/Volume of the same gas at standard conditions (m^3/Sm^3)

Bt : Total volume factor.
Volume of oil and liberated gas at P and t (from PV-relations)/volume of stock tank oil (m^3/Sm^3)

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Formulas:

Sampling:

$Fpv = 1/\sqrt{z}$

$Fg = 1/\sqrt{\gamma}$

Single flash separation:

Gas Oil Ratio:	GOR	=	Vg,sc/Vo,sc
Oil formation volume factor:	Bo	=	Vo/Vo,sc
Density of saturated oil:	ρ,oil	=	(ρ,sto + $\gamma \cdot \rho$,air·GOR)/Bo

Pressure Volume relations:

Relative volume:	Vrel	=	Vo/Vpb
Isothermal compressibility:	c	=	- (1/Vs)/(dVs/dP)
Y-function:	Y	=	a + bP
	Y	=	((Pb - P)/P)/(Vs/Vpb - 1)
Thermal expansion:	β	=	(1/Vs)/(dV/dT)

Differential liberation:

Oil formation volume factor:	Bo,i	=	Vo,i/Vo,residual,sc
Gas formation volume factor:	Bg,i	=	Vg,i/Vg,i,sc
Solution Gas Oil Ratio:	Rs,i	=	ΔVg,i,sc/Vo,sc
Total formation volume factor:	Bt,i	=	$Bo,i + Bg,i(Rs - \sum_{i=1}^{n} \Delta Rs,i)$

Multistage separator test:

The same as single stage flash.

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10. SAMPLING SHEET

The following page is the sampling sheet supplied together with the sample analysed in the PVT study. The sampling sheets for the samples not used for the PVT analyses are not included in the report.

Aker Maritime
Maritime Well Service AS
Fabrikkveien 21, P.O.Box 281, N-4033 Forus, Norway
Phone (+47) 51 81 90 00, Telefax: (+47) 51 81 90 10

BOTTOM HOLE SAMPLE

Customer	:	Statoil	Field	:	Sleipner
Rig/Platform	:	Byford Dolphin	Formation	:	Hugin
Well	:	15/9-19A	Perforations	:	3885,5-3888,5m MD RKB
Test	:	2A	Sample Depth	:	3769.2m MD RKB
BHS Run	:	1			

Bottle No : 20770 Sample No : 64

Identification		
Sample Nature	:	Oil
Date of Sampling	:	28.10.97
Start time	:	22:22
Sampling duration	:	22 mins
Sampler No	:	073
Sampler type	:	Xact Single Phase
Volume	:	700cc

Transfer Conditions		
Opening Pressure	:	375 bar
Opening Temperature	:	6 °C
Transfer Medium	:	Water/Gylcol
Transfer Duration	:	19 mins
Transfer Pressure	:	430 bar
Transfer Temperature	:	65 °C
Field Bubble Point	:	n/a at

Final Shipping Conditions		
Sample Bottle Type	:	Xmerc II
Bottle Volume	:	774 cc
Volume of Sample	:	550 cc
Nitrogen Volume	:	150 cc
Water/Glycol in Bottle	:	74 cc
Shipping Pressure	:	450 bar
Shipping Temperature	:	23 °C

Separator Conditions		
Pressure	:	at
Oil Rate	:	
Gas Rate	:	
Water Rate	:	
G.O.R.	:	
FPV	:	
Z-Factor	:	
Gas Density (air = 1)	:	

Coupled with Samples
Xmerc 20561 from Xact BHS 076
Xmerc 20830 from Xact BHS 070

Bottom Hole Conditions		
Pressure	:	322 bar
Temperature	:	111°C
At Depth	:	3748m MD RKB

Remarks :

Sampling at static conditions

Sampled by : Keith Manning