

ELARK No.: 98S9700016106(1)

 **STATOIL**

Well: 15/9-19A

DST 2A

**RECOMBINATION AND PVT ANALYSIS
CORE FLOODING STUDY
REPORT NO.: STAT617
SEPTEMBER 1998**

 **Oilphase**

LABORATORY REPORT

TITLE : Recombination and PVT Analysis
Well : 15/9-19A

Client Name and Address STATOIL 4035 STAVANGER Attn.: Tore Tjomsland	Date Sampled	27.10.97
	Date of arrival	22.04.98
	Date Analysed	-
	Date Reported	21.09.98
	Oilphase Reference	STAT617

Client Contact Person	Tore Tjomsland
Contract / Order Reference	VMS14435/49482
Number of Samples	6
Sample Type	Separator samples (oil & gas)
Sample Identification	20605, 20672, 50358, 50281, 50292 & 50267
Sampling Location	Sleipner, Theta vest
Sampling Procedure	-
Condition of Sample on arrival	-

Analysis Results

We refer to attached report.

Analysed by subcontractors	Method	Subcontractor

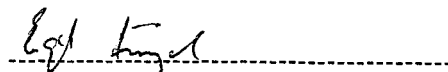
Comments

12 ex. of final report.
 The analyses are not accredited analyses.

Stavanger, 08.10.98



Anett Kristin N. Låder
 Supervisor PVT



Egil Linjord
 Chief Analyst

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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 purchase order no./contract no.: VMS14435/49482.

Company contact person: Tore Tjomsland
Oilphase contact person: Egil Linjord / Anett Kr. N. Låder

Stavanger, 21.09.98

2. SCOPE OF WORK

Two separator sample sets were recombined to supply reservoir fluid for a core flooding study. One of the recombined samples has been analysed, and the results are described in this report.

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

- Analysis of one representative separator set.
- Opening pressure of separator gas bottles.
- Physical recombination of separator oil and gas to reservoir fluid at $P = 226.5$ bar with corresponding equilibrium gas.
- Single stage flash including compositional analysis of stock tank gas and oil to C_{10+} .
- Viscosity study of reservoir fluid at reservoir temperature.

The quality of the separator gas samples was checked by measuring the opening pressures of the bottles.

The composition of the separator gas sample was determined by gas chromatography. The composition of the separator oil sample was determined by single stage flash to atmospheric pressure, followed by gas chromatographic analysis of the stabilised oil and gas.

Selected analyses were performed on the recombined reservoir fluid at given conditions.

3. SUMMARY

Reservoir Fluid Study
Well: 15/9-19A
Recombined sample

September 1998

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

The reservoir fluid was recombined to an equilibrium pressure of 226.5 bar with surplus equilibrium gas.

Single-stage flash and viscosity measurements were determined on the fluid at 110°C (reservoir temp.).

Main results:

Recombination-/equilibrium pressure	:	226.5	bar
Viscosity at equilibrium pressure	:	0.753	mPas

From single-stage flash:

Gas/oil ratio	:	113.9	Sm ³ /Sm ³
B _o at 304.6 bar	:	1.377	m ³ /Sm ³
Density of stock tank oil at standard conditions	:	904.6	kg/Sm 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

4. SAMPLE

The separator samples from 15/9-19A Test 2A for the PVT analysis were supplied by STATOIL.

Field	:	Sleipner, Theta Vest	
Well	:	15/9-19A	
Test	:	2A, Clean up	
Interval tested, perforations	:	3888.5 - 3885.5 m MD RKB 3074.9 - 3077.5 m TVD MSL	
Producing zone/sampling	:	-	
Reservoir fluid	:	Separator oil and gas	
Static bottom hole conditions:			
Reservoir pressure	:	340	bar
Reservoir temperature	:	110.0	°C
Date of sampling	:	27.10.97	
Time of sampling	:	18:48-19:10 (no. 20605) 18:49-19:15 (no. 50267) 18:49-19:15 (no. 50358) 20:03-20:31 (no. 20672) 20:04-20:33 (no. 50281) 20:04-20:33 (no. 50292)	
Type of samples			
PVT-set no. 1	:	20605, 50267 & 50358	
PVT-set no. 2	:	20672, 50281 & 50292	
Oil bottle	:	20605	Sample no. 44
		20672	Sample no. 47
Gas bottle	:	50267	Sample no. 45
		50358	Sample no. 46
		50281	Sample no. 48
		50292	Sample no. 49
Separator conditions			
Separator pressure	:	15.3	bar
Separator temperature	:	34.9	°C
Flow rates			
Separator gas rate	:	26443	Sm ³ /D (set no. 1)
		26547	Sm ³ /D (set no. 2)
Separator oil rate	:	295	m ³ /D (set no. 1)
		292	m ³ /D (set no. 2)
Gas-oil ratio	:	89.6	Sm ³ / Sm ³ (set 1)
		90.9	Sm ³ / Sm ³ (set 2)
Gas gravity	:	0.738	(set no. 1 & 2)
z-factor	:	0.963	(set no. 1)
		0.964	(set no. 2)

5. VALIDITY CHECK

The opening pressure was measured on the gas samples.

The composition of the separator gas was determined on one selected gas sample, bottle no. 20605.

Separator samples, oil

Sample no.:	Bottle no.:	Temperature °C	Bubble point pressure, bar	Sep. pressure Bar	Sep. temp °C
44	20605	34.9	15	15.3	34.9

Opening pressure of separator gas bottles

Sample no.:	Bottle no.:	Temperature °C	Opening pressure, bar	Coupled with	Sep. press. Bar	Sep. Temp. °C
45	50267	60	16.2	20605 & 50358	15.3	34.9
46	50358	60	16.1	20605 & 50267	15.3	34.9

6. COMMENTS

All the separator oil was used for the recombination.

We received approx. 300-400 cc less separator oil than needed for the ordered amount of physical recombined reservoir fluid. This is the reason for why ResLab received less recombined reservoir fluid than expected.

The recombined reservoir fluid was sent to ResLab, attn. Marit Ringheim, for further analysis.

HHC-Plot: The accuracy of a compositional analysis from the equilibrium phases of a reservoir sample can be plotted graphically using a HHC plot (Hoffman, Crump and Hocott). The graph is generated by plotting for each hydrocarbon (C2 to C9) the log of the product KP (the equilibrium constant times the absolute pressure) against a function $b(1/TB - 1/T)$, where b is a constant characteristic of the particular hydrocarbon, TB is boiling point, and T the temperature. It has been found empirically that for the equilibrium between a gas and a liquid at any given pressure, the logarithms of the KP products for the individual hydrocarbons so plotted yield reasonable straight lines against the function $b(1/TB - 1/T)$.

The figures on page 17 and 24 show HHC-plots for each sample.

7. PHYSICAL RECOMBINATION OF RESERVOIR FLUID

Volume of gas injected in the PVT cell = 214 934 cc

GOR calculated to separator conditions:

$$\text{GOR}_{\text{sep}} = 215 \text{ Sm}^3/\text{m}^3 \text{ sep.oil}$$

Volume of separator oil at separator conditions:

$$V_{\text{or BP}} = \frac{214\,934}{215} = 999.7 \text{ cc}$$

Volume of separator oil at separator temperature and 150 bar.

$$V_o = 999.7 \cdot 0.9899 \cdot 0.9918 = 981.5 \text{ cc}$$

Recombination temperature : 110.0°C

8. PRESSURE-VOLUME RELATIONS OF SEPARATOR FLUID

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PRESSURE-VOLUME RELATION OF SEPARATOR LIQUID
AT 34.9 °C AND CONSTANT MASS

Bottle no.: 20605

Pressure bar	Relative volume V/V_{bp}	Isothermal compressibility bar^{-1}
177.8	0.9881	$0.67 \cdot 10^{-4}$
153.8	0.9898	$0.69 \cdot 10^{-4}$
128.9	0.9914	$0.71 \cdot 10^{-4}$
104.4	0.9933	$0.73 \cdot 10^{-4}$
79.7	0.9950	$0.75 \cdot 10^{-4}$
55.4	0.9968	$0.77 \cdot 10^{-4}$
32.3	0.9986	$0.78 \cdot 10^{-4}$
20.3	0.9997	$0.79 \cdot 10^{-4}$
15.0	1.0000	$0.80 \cdot 10^{-4}$
14.4	1.0161	
12.5	1.0784	
10.6	1.1744	
8.8	1.3199	
7.1	1.5441	
5.8	1.8089	

Best fit V equation above bubble point :

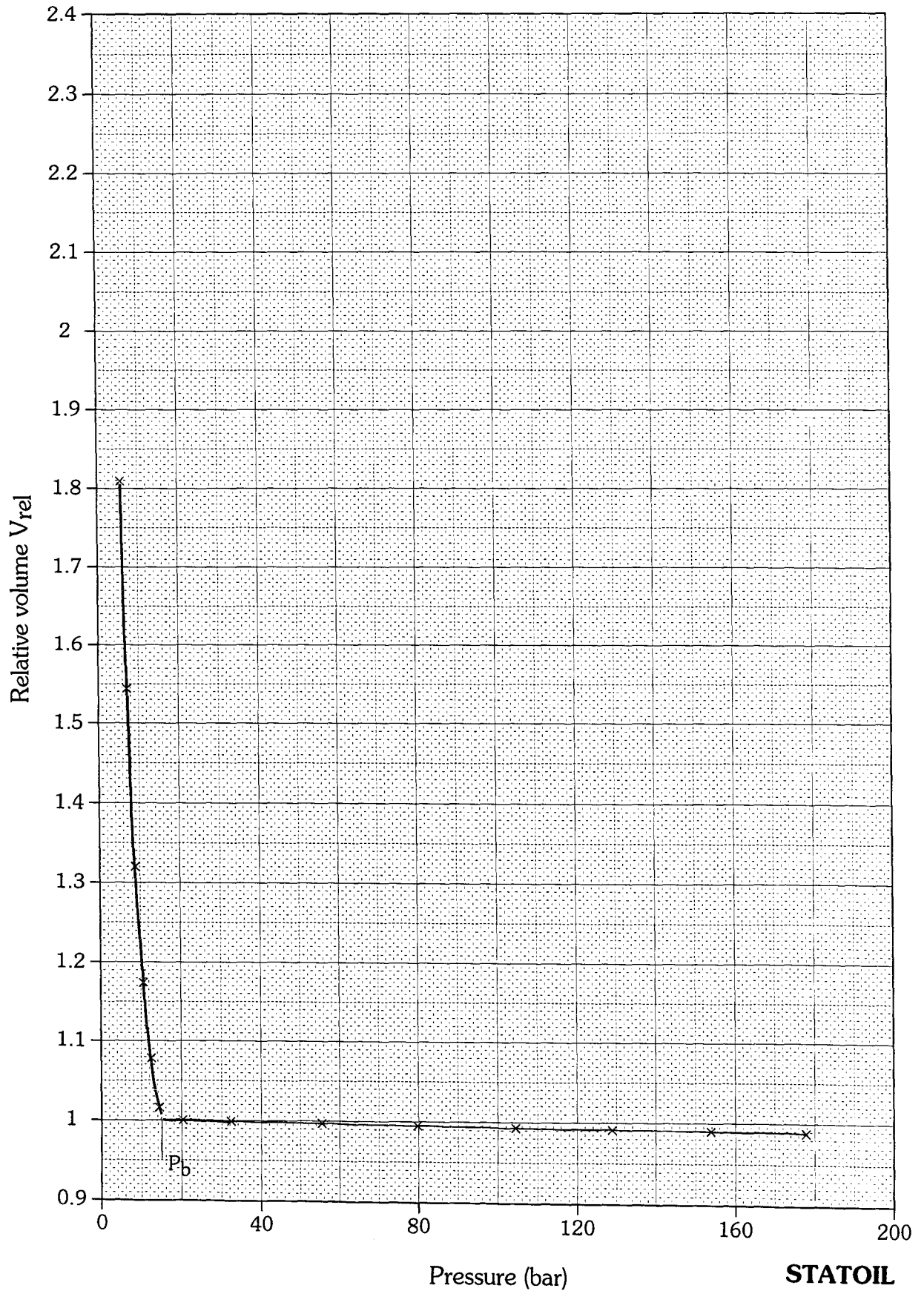
$$V_{rel} = 1.0012 - 0.809 \cdot 10^{-4} p + 0.418 \cdot 10^{-7} p^2$$

Pressure-volume relation, see fig 1.

Fig. 1

**PRESSURE - VOLUME RELATION OF SEPARATOR LIQUID
AT 34.9 °C AND CONSTANT MASS**

$P_b = 15.0$ bar



9. SINGLE STAGE FLASH OF SEPARATOR FLUID

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FLASH OF SEPARATOR LIQUID TO STOCK TANK CONDITIONS.

Bottle no. 20605

Flash conditions: 151 bar and 34.9°C to atmosphere and 20°C.

Gas oil ratio	:	11.1	Sm ³ /Sm ³	1)
B _o at 151 bar	:	1.051	m ³ /Sm ³	2)
B _o at bubble point (P _{bp} = 15.0 bar)	:	1.061	m ³ /Sm ³	3)
Density of oil at 15°C	:	894.7	kg/Sm ³	
Density of fluid at bubble point pressure	:	857.5	kg/Sm ³	
Molecular weight of dead oil (measured)	:	244		
Gas gravity (air = 1)	:	1.140		
Molecular weight of C ₇₊ (calculated)	:	285		4)
Density of C ₇₊ (calculated)	:	918	kg/Sm ³	4)
Molecular weight of C ₁₀₊ (calculated)	:	338		4)
Density of C ₁₀₊ (calculated)	:	936	kg/Sm ³	4)

- 1) Standard m³ gas per Sm³ stock tank oil.
- 2) m³ of separator liquid at 151 bar per Sm³ stock tank oil.
- 3) m³ of separator liquid at bubble point per Sm³ stock tank oil.
- 4) Stock tank oil.

FLASH OF SEPARATOR LIQUID TO STOCK TANK CONDITIONS

MOLECULAR COMPOSITION AND PNA DISTRIBUTION

BOTTLE NO. 20605

Stock tank gas

Component	Wt%	mol%	molwt.	LNG 1)
Nitrogen	0.82	0.97		
Carbon dioxide	4.26	3.20		
Methane	18.77	38.67		
Ethane	17.84	19.61		
Propane	31.24	23.42		860.6
iso-Butane	4.64	2.64		115.1
n-Butane	13.17	7.49		315.3
iso-Pentane	3.01	1.38		67.5
n-Pentane	3.34	1.53		74.1
Hexanes	1.66	0.66	83.4	35.0
P	1.42	0.55		
N	0.24	0.11		
A	0.00	0.00		
Heptanes	0.72	0.27	87.4	14.7
P	0.16	0.05		
N	0.44	0.17		
A	0.12	0.05		
Octanes	0.35	0.11	103.0	6.9
Nonanes	0.18	0.05	117.0	3.5
Decanes plus	0.00	0.001	156	0.1
Sum	100.00	100.001		1492.8

Average molecular weight : 33.06

1) Liquefied natural gas as m³ liquid/10⁶ Sm³ gas

FLASH OF SEPARATOR LIQUID TO STOCK TANK CONDITIONS

MOLECULAR COMPOSITION AND PNA DISTRIBUTION

BOTTLE NO. 20605

Stock tank oil

Component	Wt%	mol%	molwt.	density kg/m ³
Nitrogen	-	-		
Carbon dioxide	-	-		
Methane	-	-		
Ethane	0.06	0.45		
Propane	0.55	3.04		
iso-Butane	0.20	0.84		
n-Butane	1.00	4.19		
iso-Pentane	0.60	2.01		
n-Pentane	1.00	3.39		
Hexanes	1.69	4.88	84.4	669
P	1.54	4.35		
N	0.15	0.53		
A	0.00	0.00		
Heptanes	2.73	7.30	91.2	738
P	1.30	3.20		
N	1.05	2.90		
A	0.38	1.20		
Octanes	2.76	6.37	105.6	758
P	1.13	2.41		
N	1.14	2.67		
A	0.49	1.29		
Nonanes	2.29	4.64	120.2	767
P	1.20	2.29		
N	0.59	1.21		
A	0.50	1.14		
Decanes plus	87.12	62.89	338	936
Sum	100.00	100.00		
Average molecular weight :			244	

MATHEMATICALLY RECOMBINED SEPARATOR LIQUID

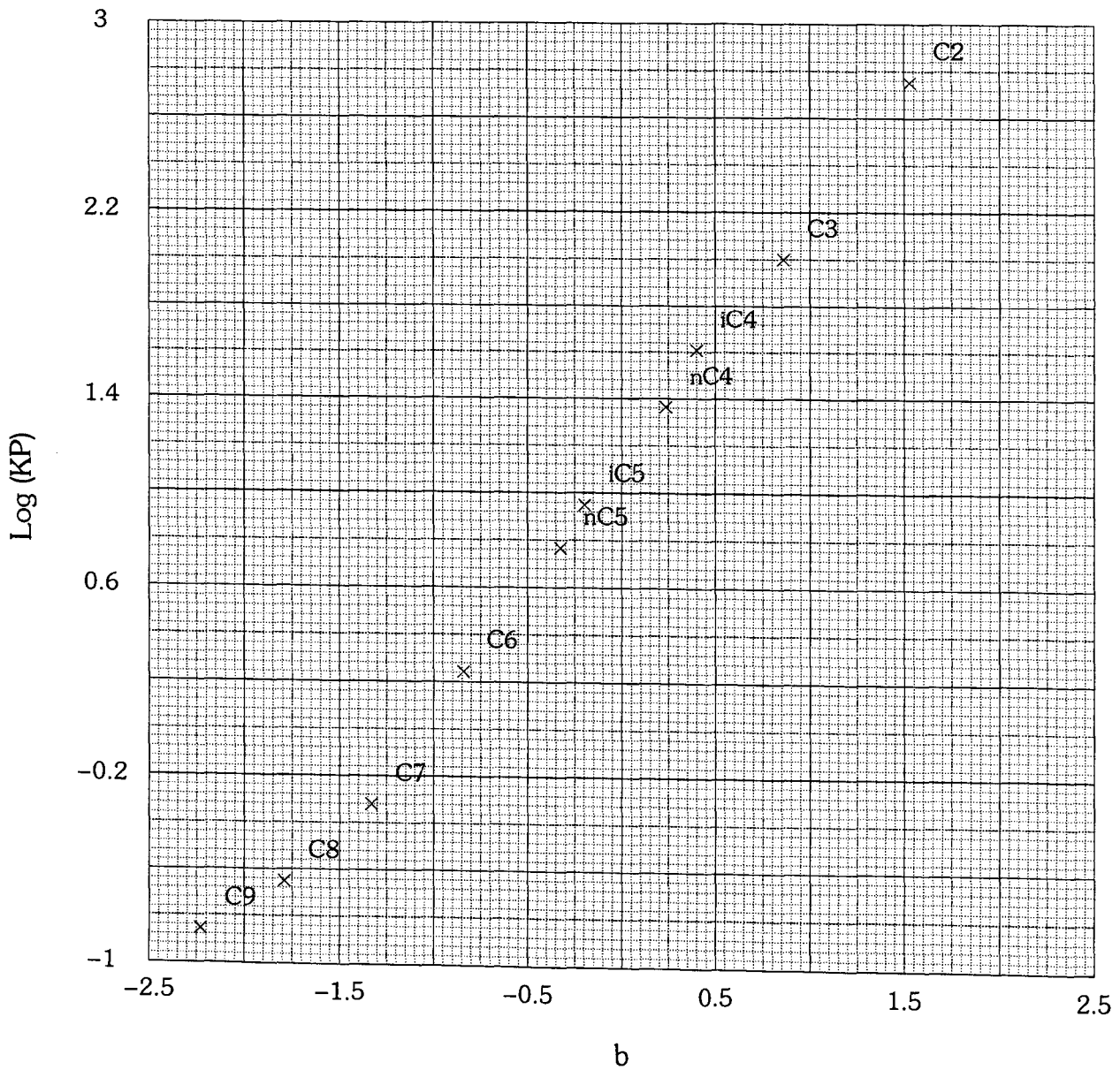
MOLECULAR COMPOSITION AND PNA DISTRIBUTION

BOTTLE NO. 20605

Component	Wt%	mol%	molwt.
Nitrogen	0.01	0.11	
Carbon dioxide	0.07	0.36	
Methane	0.32	4.38	
Ethane	0.36	2.62	
Propane	1.07	5.35	
iso-Butane	0.28	1.05	
n-Butane	1.21	4.57	
iso-Pentane	0.64	1.94	
n-Pentane	1.04	3.18	
Hexanes	1.69	4.40	84.4
P	1.54	3.92	
N	0.15	0.48	
A	0.00	0.00	
Heptanes	2.70	6.50	91.2
P	1.28	2.84	
N	1.04	2.59	
A	0.38	1.07	
Octanes	2.72	5.66	105.6
P	1.12	2.14	
N	1.12	2.38	
A	0.48	1.14	
Nonanes	2.25	4.12	120.2
P	1.18	2.04	
N	0.58	1.07	
A	0.49	1.01	
Decanes plus	85.64	55.76	338
Sum	100.00	100.00	
Average molecular weight :			200

HHC Plot

STATOIL STAT617 Brønn 15/9-19A Flnr.20605 SF sep.set.



COMPOSITION ANALYSIS OF SEPARATOR GAS

MOLECULAR COMPOSITION AND PNA DISTRIBUTION

Bottle no.: 50267

Component	Wt%	mol%	molwt.	LNG 1)
Nitrogen	1.30	0.99		
Carbon dioxide	6.26	3.05		
Methane	58.19	77.88		
Ethane	12.94	9.24		
Propane	11.83	5.76		211.6
iso-Butane	1.41	0.52		22.7
n-Butane	3.92	1.45		60.9
iso-Pentane	0.95	0.28		13.8
n-Pentane	1.18	0.35		17.0
Hexanes	0.86	0.22	83.9	11.8
P	0.76	0.19		
N	0.10	0.03		
A	0.00	0.00		
Heptanes	0.78	0.19	89.8	10.3
P	0.28	0.06		
N	0.37	0.09		
A	0.13	0.04		
Octanes	0.31	0.06	103.0	4.0
Nonanes	0.07	0.01	117.0	0.9
Decanes plus	0.00	0.00		
Sum	100.00	100.00		353.0
Average molecular weight :			21.47	
Gas gravity :		0.741		

1) Liquified natural gas as m³ liquid/10⁶ Sm³ gas

10. SINGLE STAGE FLASH OF RECOMBINED RESERVOIR FLUID

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FLASH OF RESERVOIR LIQUID TO STOCK TANK CONDITIONS

Recombined reservoir fluid

Flash conditions: 304.6 bar and 110°C to atmosphere and 20°C.

Gas oil ratio	:	113.9	Sm ³ /Sm ³	1)
B _o at 304.6 bar	:	1.377	m ³ /Sm ³	2)
Density of oil at 15°C	:	904.6	kg/Sm ³	
Molecular weight of dead oil (measured)	:	262		
Gas gravity (air = 1)	:	0.883		
Molecular weight of C ₇₊ (calculated)	:	287		3)
Density of C ₇₊ (calculated)	:	918	kg/Sm ³	3)
Molecular weight of C ₁₀₊ (calculated)	:	342		3)
Density of C ₁₀₊ (calculated)	:	936	kg/Sm ³	3)

- 1) Standard m³ gas per Sm³ stock tank oil.
- 2) m³ of separator liquid at 304.6 bar per Sm³ stock tank oil.
- 3) m³ of separator liquid at bubble point per Sm³ stock tank oil.
- 4) Stock tank oil.

FLASH OF RESERVOIR FLUID TO STOCK TANK CONDITIONS

MOLECULAR COMPOSITION AND PNA DISTRIBUTION

Recombined reservoir fluid

Stock tank gas

Component	Wt%	mol%	molwt.	LNG 1)
Nitrogen	0.62	0.57		
Carbon dioxide	5.48	3.18		
Methane	41.79	66.57		
Ethane	13.86	11.78		
Propane	16.87	9.78		359.3
iso-Butane	2.49	1.10		47.8
n-Butane	7.99	3.51		147.9
iso-Pentane	2.41	0.86		41.8
n-Pentane	3.14	1.11		53.8
Hexanes	2.45	0.75	83.8	39.9
P	2.14	0.64		
N	0.31	0.11		
A	0.00	0.00		
Heptanes	2.09	0.60	89.3	32.9
P	0.68	0.17		
N	1.06	0.32		
A	0.35	0.11		
Octanes	0.68	0.16	105.8	10.4
Nonanes	0.12	0.03	120.1	1.8
Decanes plus	0.01	0.00	156	0.2
Sum	100.00	100.00		735.8

Average molecular weight : 25.56

1) Liquefied natural gas as m³ liquid/10⁶ Sm³ gas

FLASH OF RESERVOIR FLUID TO STOCK TANK CONDITIONS

MOLECULAR COMPOSITION AND PNA DISTRIBUTION

Recombined reservoir fluid

Stock tank oil

Component	Wt%	mol%	molwt.	density kg/m ³
Nitrogen	-	-		
Carbon dioxide	-	-		
Methane	-	-		
Ethane	0.02	0.15		
Propane	0.18	1.06		
iso-Butane	0.08	0.38		
n-Butane	0.42	1.91		
iso-Pentane	0.35	1.29		
n-Pentane	0.64	2.32		
Hexanes	1.39	4.33	84.4	669
P	1.26	3.85		
N	0.13	0.48		
A	0.00	0.00		
Heptanes	2.61	7.51	91.3	739
P	1.23	3.26		
N	1.02	3.03		
A	0.36	1.22		
Octanes	2.98	7.39	105.8	758
P	1.22	2.80		
N	1.24	3.11		
A	0.52	1.48		
Nonanes	2.56	5.60	120.1	767
P	1.34	2.76		
N	0.65	1.44		
A	0.57	1.40		
Decanes plus	88.77	68.06	342	936
Sum	100.00	100.00		
Average molecular weight :			262	

MATHEMATICALLY RECOMBINED RESERVOIR FLUID

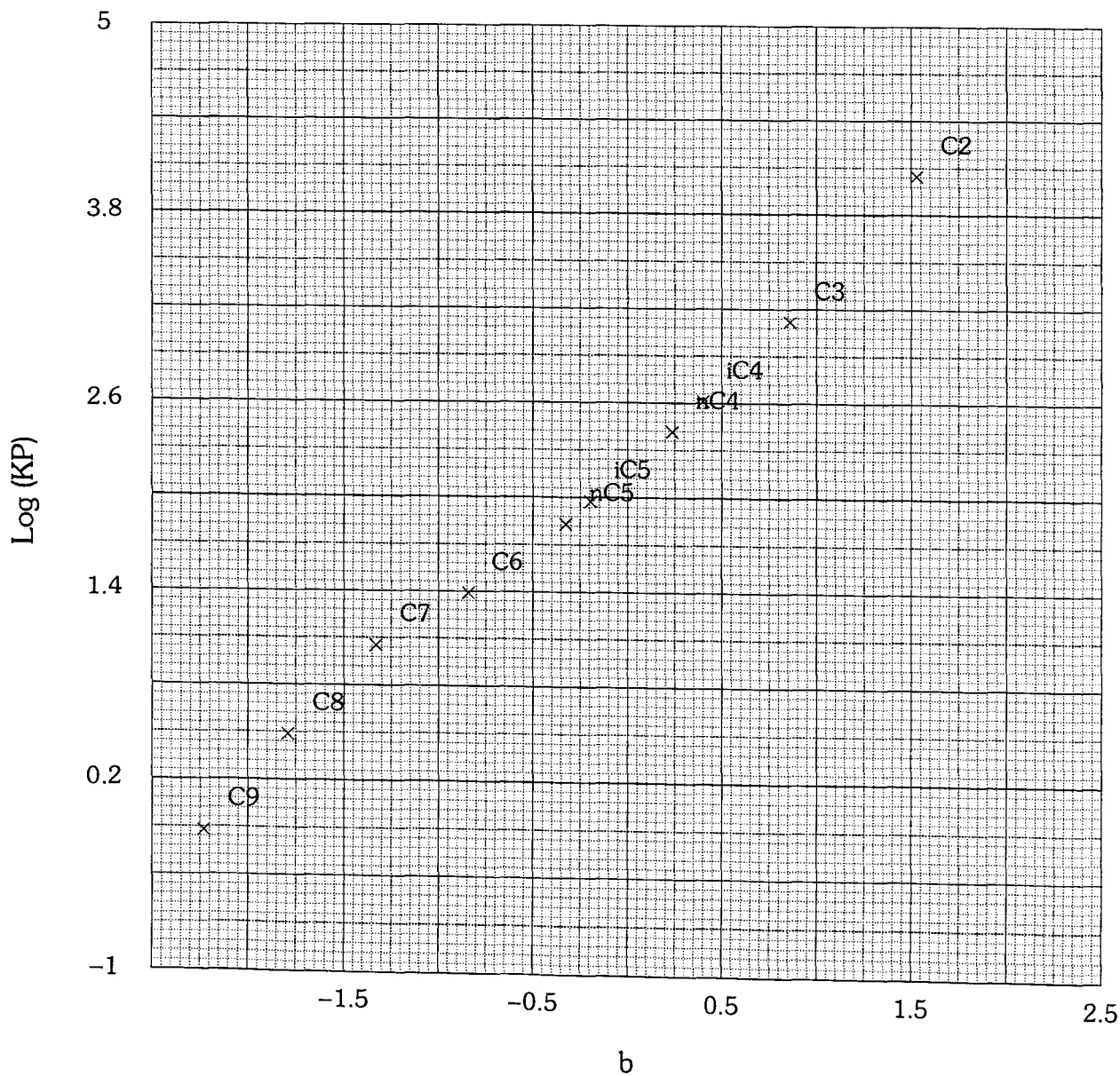
MOLECULAR COMPOSITION AND PNA DISTRIBUTION

Recombined reservoir fluid

Component	Wt%	mol%	molwt.
Nitrogen	0.07	0.33	
Carbon dioxide	0.66	1.86	
Methane	5.01	38.81	
Ethane	1.68	6.93	
Propane	2.18	6.14	
iso-Butane	0.37	0.80	
n-Butane	1.33	2.84	
iso-Pentane	0.60	1.04	
n-Pentane	0.94	1.62	
Hexanes	1.52	2.24	84.3
P	1.37	1.97	
N	0.15	0.27	
A	0.00	0.00	
Heptanes	2.55	3.48	90.9
P	1.17	1.46	
N	1.02	1.44	
A	0.36	0.58	
Octanes	2.70	3.18	105.8
P	1.11	1.21	
N	1.12	1.33	
A	0.47	0.64	
Nonanes	2.27	2.35	120.1
P	1.20	1.15	
N	0.57	0.61	
A	0.50	0.59	
Decanes plus	78.12	28.38	342
Sum	100.00	100.00	
Average molecular weight :			124

HHC Plot

STAT617 15/9-19A Rek.res.fluid



EQUILIBRIUM GAS FROM RECOMBINATION

MOLECULAR COMPOSITION AND PNA DISTRIBUTION

Component	Wt%	mol%	molwt.	LNG 1)
Nitrogen	1.55	1.19		
Carbon dioxide	5.74	2.81		
Methane	59.20	79.47		
Ethane	10.92	7.82		
Propane	9.92	4.84		178.0
iso-Butane	1.33	0.49		21.5
n-Butane	3.94	1.46		61.5
iso-Pentane	1.26	0.38		18.4
n-Pentane	1.69	0.51		24.4
Hexanes	1.71	0.44	84.3	23.5
P	1.54	0.39		
N	0.17	0.05		
A	0.00	0.00		
Heptanes	1.63	0.39	91.0	21.6
P	0.66	0.14		
N	0.77	0.20		
A	0.20	0.05		
Octanes	0.57	0.12	103.0	7.3
Nonanes	0.11	0.02	117.0	1.4
Decanes plus	0.43	0.06	156	5.3
Sum	100.00	100.00		363.0
Average molecular weight :			21.54	
Gas gravity :			0.743	

1) Liquefied natural gas as m³ liquid/10⁶ Sm³ gas

11. VISCOSITY OF RESERVOIR FLUID

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Viscosity of reservoir liquid at reservoir temperature	27-28

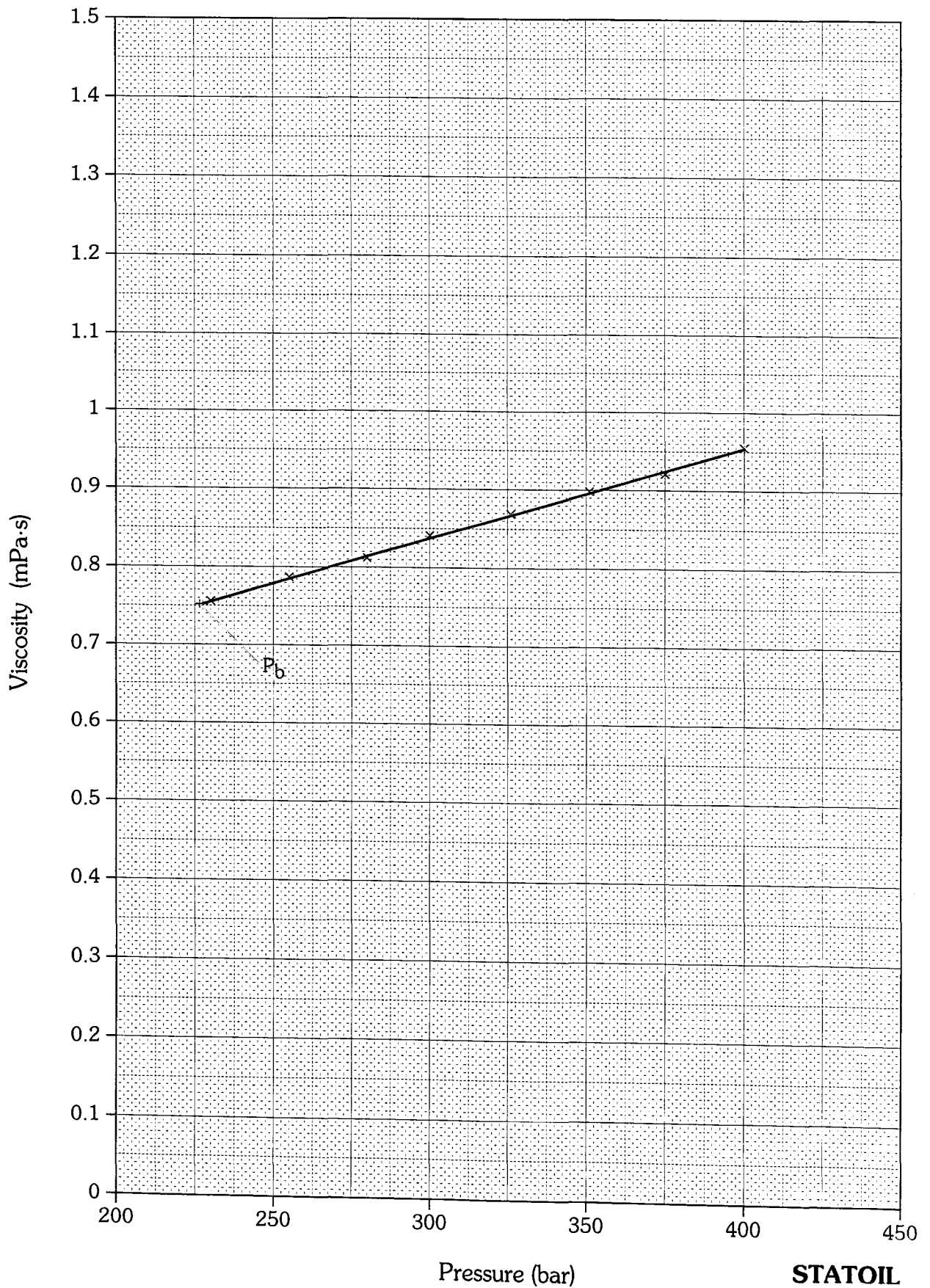
VISCOSITY OF RESERVOIR FLUID AT 110°C

Pressure m (bar)	Viscosity (mPa·s)
400.0	0.955
375.0	0.921
351.0	0.898
326.0	0.869
300.0	0.841
280.0	0.812
255.0	0.787
230.0	0.756

Viscosity, see fig. 3

Fig. 3

VISCOSITY OF RESERVOIR LIQUID AT 110.0°C



12. LABORATORY PROCEDURES

PVT-analysis

Pressure-volume relations of reservoir fluid were performed in a Ruska PVT cell. Single flash of reservoir fluid to 20°C and atmospheric pressure was performed in a glass Flash Separator. Gas volumes were measured by a ROP Gasometer. Gas samples for analysis were collected in a gas sampling tube (250 ml) connected between the separator and 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 stainless steel column (4'x1/8", 80-100 mesh). The light gases, O₂, N₂ and methane were separated on a stainless steel molecular sieve column (10'x1/8", 13x45-60). CO₂ and ethane were separated on a stainless steel 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 6890 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.

For the quantification Iso-octane is used as an internal standard. The molecular weights and the densities are calculated from the detailed composition on the fractions from C6 to C10+.

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.

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

The formula is:

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

Molecular weight

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

Accuracy for the analysis: +/- 1%.

Viscosity

Liquid viscosity was determined with a ROP rolling ball viscosimeter calibrated with viscosity standards from Cannon Instrument Co.

The reservoir fluid was exposed to pressure steps in a process similar to constant mass expansion and the viscosity measurements was made on the liquid phase at each step.

Repeatability: +/- 3-4%.

Gas viscosity is calculated from molecular composition according to Lee, A.L., Gonzales, M.H. and Eakin, B.E., J. Petr. Techn. 1966, 977-1000.

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 ·bar/g mol·K

P_{BP}	:	Bubblepoint pressure (barg or bara)
B_o	:	Oil formation volume factor Volume of reservoir oil at P and t/Volume of stock tank oil (STO) (m ³ /Sm ³)
V_{rel}	:	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
R_s	:	Solution gas oil ratio. Gas in solution at P and t (Sm ³ /STO (m ³))
B_g	:	Gas formation volume factor. Volume of gas at P and t/Volume of the same gas at standard conditions (m ³ /Sm ³)
B_t	:	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)

Formulas:

Sampling:

$$F_{pv} = 1/\sqrt{z}$$

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

Single flash separation:

Gas Oil Ratio: $GOR = V_{g,sc}/V_{o,sc}$

Oil formation volume factor: $B_o = V_o/V_{o,sc}$

Density of saturated oil: $\rho_{oil} = (\rho_{sto} + \gamma \rho_{air} \cdot GOR)/B_o$

Pressure Volume relations:

Relative volume: $V_{rel} = V_o/V_{pb}$

Isothermal compressibility: $c = -(1/V_s)/(dV_s/dP)$

Y-function: $Y = a + bP$
 $Y = ((P_b - P)/P)/(V_s/V_{pb} - 1)$

Thermal expansion: $\beta = (1/V_s)/(dV/dT)$

Differential liberation:

Oil formation volume factor: $B_{o,i} = V_{o,i}/V_{o,residual,sc}$

Gas formation volume factor: $B_{g,i} = V_{g,i}/V_{g,i,sc}$

Solution Gas Oil Ratio: $R_{s,i} = \Delta V_{g,i,sc}/V_{o,sc}$

Total formation volume factor: $B_{t,i} = B_{o,i} + B_{g,i}(R_s - \sum_{i=1}^n \Delta R_{s,i})$

Multistage separator test:

The same as single stage flash.

13. SAMPLING SHEET

The following pages are sampling sheets supplied together with the samples analysed in the PVT study.

PVT-SET NO. 1

Customer	: Statoil	Field	: Sleipner, Theta vest
Rig/Platform	: Byford Dolphin	Formation	: Hugin
Well	: 15/9-19A	Perforations	: 3888.5 -
Test	: 2A, Clean up		3885.5 m MD RKB

Bottle No : 20605

Sample No : 44

Identification

Fluid Type	: Separator oil	Start Sampling	: 18:48
Sampling Point	: Sep. oil outlet	Stop Sampling	: 19:10
Sampling Date	: 27.10.97	Sampling Duration	: 22 min
		Coupled with	: 50267 50358

Separator Conditions During Sampling

Pressure	: 15.3	G.O.R.	: 89.6 Sm ³ / Sm ³
Temperature	: 34.9	FPV	: 1.0188
Oil Rate	: 295	Z-Factor	: 0.9634
Gas Rate	: 26 443	Gas Gravity (air = 1)	: 0.738
Water Rate	: 0	Oil Density (at 15°C)	: 0.892

Bottle Information

Bottle type	: X-mercll	Gas Cap Volume	: 30 ml.
Bottle Volume	: 720 ml.	Water/Glycol in Bottle	: 140 ml.
Sample Volume	: 550 ml.	Shipping Pressure	: 7 bar at 10 °C

Remarks : Due to wrong type of sensor, the scale in oil bottle pressure graph is wrong

Sampled by : TWG/RB



PVT-SET NO. 1

Customer	: Statoil	Field	: Sleipner, Theta vest
Rig/Platform	: Byford Dolphin	Formation	: Hugin
Well	: 15/9-19A	Perforations	: 3888.5 -
Test	: 2A, Clean up		: 3885.5 m MD RKB

Bottle No : 50267

Sample No : 45

Identification

Fluid Type	: Separator gas	Start Sampling	: 18:49
Sampling Point	: Sep. gas outlet	Stop Sampling	: 19:15
Sampling Date	: 27.10.97	Sampling Duration	: 26 min
		Coupled with	: 20605 50358

Separator Conditions During Sampling

Pressure	: 15.3	G.O.R.	: 89.6 Sm ³ / Sm ³
Temperature	: 34.9	FPV	: 1.0188
Oil Rate	: 295	Z-Factor	: 0.9634
Gas Rate	: 26 443	Gas Gravity (air = 1)	: 0.738
Water Rate	: 0	Oil Density (at 15°C)	: 0.892

Bottle Information

Bottle type	: X-ample	Gas Cap Volume	:
Bottle Volume	: 20 litre	Water/Glycol in Bottle	:
Sample Volume	: 20 litre	Shipping Pressure	: 14 bar at 10 °C

Remarks :

Sampled by : TWG/RB

Åringsstrykk målt 27/8-98 v/60°C
Piping = 15,2 barg



PVT-SET NO. 1

Customer	: Statoil	Field	: Sleipner, Theta vest
Rig/Platform	: Byford Dolphin	Formation	: Hugin
Well	: 15/9-19A	Perforations	: 3888.5 -
Test	: 2A, Clean up		: 3885.5 m MD RKB

Bottle No : 50358

Sample No : 46

Identification

Fluid Type	: Separator gas	Start Sampling	: 18:49
Sampling Point	: Sep. gas outlet	Stop Sampling	: 19:15
Sampling Date	: 27.10.97	Sampling Duration	: 26 min
		Coupled with	: 20605 50267

Separator Conditions During Sampling

Pressure	: 15.3	G.O.R.	: 89.6 Sm ³ / Sm ³
Temperature	: 34.9	FPV	: 1.0188
Oil Rate	: 295	Z-Factor	: 0.9634
Gas Rate	: 26 443	Gas Gravity (air = 1)	: 0.738
Water Rate	: 0	Oil Density (at 15°C)	: 0.892

Bottle Information

Bottle type	: X-ample	Gas Cap Volume	:
Bottle Volume	: 20 litre	Water/Glycol in Bottle	:
Sample Volume	: 20 litre	Shipping Pressure	: 14 bar at 10 °C

Remarks :

Empty box for remarks.

Sampled by : TWG/RB



PVT-SET NO. 2

Customer	: Statoil	Field	: Sleipner, Theta vest
Rig/Platform	: Byford Dolphin	Formation	: Hugin
Well	: 15/9-19A	Perforations	: 3888.5 -
Test	: 2A, Clean up		: 3885.5 m MD RKB

Bottle No : 20672

Sample No : 47

Identification

Fluid Type	: Separator oil	Start Sampling	: 20:03
Sampling Point	: Sep. oil outlet	Stop Sampling	: 20:31
Sampling Date	: 27.10.97	Sampling Duration	: 28 min
		Coupled with	: 50281 50292

Separator Conditions During Sampling

Pressure	: 15.4	G.O.R.	: 90.9 Sm ³ / Sm ³
Temperature	: 37.3	FPV	: 1.0185
Oil Rate	: 292	Z-Factor	: 0.9639
Gas Rate	: 26 547	Gas Gravity (air = 1)	: 0.738
Water Rate	: 0	Oil Density (at 15°C)	: 0.892

Bottle Information

Bottle type	: X-mercil	Gas Cap Volume	: 30 ml.
Bottle Volume	: 720 ml.	Water/Glycol in Bottle	: 140 ml.
Sample Volume	: 550 ml.	Shipping Pressure	: 6 bar at 10 °C

Remarks : Due to wrong type of sensor, the scale in oil bottle pressure graph is wrong

Sampled by :RB



PVT-SET NO. 2

Customer	: Statoil	Field	: Sleipner, Theta vest
Rig/Platform	: Byford Dolphin	Formation	: Hugin
Well	: 15/9-19A	Perforations	: 3888.5 -
Test	: 2A, Clean up		: 3885.5 m MD RKB

Bottle No : 50281

Sample No : 48

Identification

Fluid Type	: Separator gas	Start Sampling	: 20:04
Sampling Point	: Sep. gas outlet	Stop Sampling	: 20:33
Sampling Date	: 27.10.97	Sampling Duration	: 29 min
		Coupled with	: 20672
			: 50292

Separator Conditions During Sampling

Pressure	: 15.4	G.O.R.	: 90.9 Sm ³ / Sm ³
Temperature	: 37.3	FPV	: 1.0185
Oil Rate	: 292	Z-Factor	: 0.9639
Gas Rate	: 26 547	Gas Gravity (air = 1)	: 0.738
Water Rate	: 0	Oil Density (at 15°C)	: 0.892

Bottle Information

Bottle type	: X-ample	Gas Cap Volume	:
Bottle Volume	: 20 litre	Water/Glycol in Bottle	:
Sample Volume	: 20 litre	Shipping Pressure	: 14 bar at 10 °C

Remarks :

Sampled by :RB



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

PVT SAMPLE

PVT-SET NO. 2

Customer	: Statoil	Field	: Sleipner, Theta vest
Rig/Platform	: Byford Dolphin	Formation	: Hugin
Well	: 15/9-19A	Perforations	: 3888.5 -
Test	: 2A, Clean up		3885.5 m MD RKB

Bottle No : 50292

Sample No : 49

Identification

Fluid Type	: Separator gas	Start Sampling	: 20:04
Sampling Point	: Sep. gas outlet	Stop Sampling	: 20:33
Sampling Date	: 27.10.97	Sampling Duration	: 29 min
		Coupled with	: 50281
			50292

Separator Conditions During Sampling

Pressure	: 15.4	G.O.R.	: 90.9 Sm ³ / Sm ³
Temperature	: 37.3	FPV	: 1.0185
Oil Rate	: 292	Z-Factor	: 0.9639
Gas Rate	: 26 547	Gas Gravity (air = 1)	: 0.738
Water Rate	: 0	Oil Density (at 15°C)	: 0.892

Bottle Information

Bottle type	: X-ample	Gas Cap Volume	:
Bottle Volume	: 20 litre	Water/Glycol in Bottle	:
Sample Volume	: 20 litre	Shipping Pressure	: 14 bar at 10 °C

Remarks :

Sampled by :RB

Sjøhagen 3, Hillevåg,
4016 Stavanger.
Tlf.: 51 58 00 90

GPL

Rev. no.: 1
Date: 10.10.95
Approved, Sign.: por

Schlumberger
GeoQuest

OVERFØRING AV PVT-PRØVER

FIRMA: STATOIL

BRØNN: 15/4-19A

JOBBNR.: STAT 617

SIGN.: OW

DATO: 9/9-98

PRØVETYPE: GASS

DYBDE: _____

PVT-KAMMER NR.: RECOMBINERINNASSELLE

TIL FLASKENR.: TS-28705

REKKEFØLGE NR.: 1 AV 2

FYLLING AV FLASKE

FLASKEVOLUM: 600 cm³

PRØVEVOLUM: 500 cm³ ved 225.5 barg

GLYKOL VOLUM UT FOR TRYKKSÆNKNING: _____ cm³

GLYKOL VOLUM IGJEN I FLASKE: _____ cm³

TRYKK I FLASKE ETTER OVERFØRING: 225.5 barg

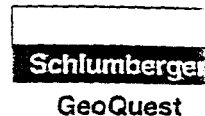
STATUS PRØVEVOLUM I FLASKE

DATO	VOLUM UT, ENFASE	TRYKK ETTER OVERF.	SIGNATUR

Merknader:

Sjøhagen 3, Hillevåg,
4016 Stavanger.
Tlf.: 51 58 00 90

GPL	
Rev. no.:	1
Date:	10.10.95
Approved, Sign.:	for



OVERFØRING AV PVT-PRØVER

FIRMA: STATOIL BRØNN: 15/9-19A
JOBBNR.: STAT 617 SIGN.: O.W.
DATO: 9/9-95 PRØVETYPE: GASS
DYBDE: _____ PVT-KAMMER NR.: REKOMMUNISERINGSCELLE
TIL FLASKENR.: TS-28805 REKKEFØLGE NR.: 2 AV 2

FYLING AV FLASKE

FLASKEVOLUM: 600 cm³
PRØVEVOLUM: 98.2 cm³ ved 225.5 barg
GLYKOL VOLUM UT FOR TRYKKSSENKNING: _____ cm³
GLYKOL VOLUM IGJEN I FLASKE: _____ cm³
TRYKK I FLASKE ETTER OVERFØRING: 222.1 barg

STATUS PRØVEVOLUM I FLASKE

DATO	VOLUM UT, ENFASE	TRYKK ETTER OVERF.	SIGNATUR

Merknader: NB: Det ble funnet spor av olje i overføringstubingen; det kan derfor være olje i gassen.

Sjøhagen 3, Hillevåg,
4016 Stavanger.
Tlf.: 51 58 00 90

GPL

Rev. no.: 1
Date: 10.10.95
Approved, Sign.: for

Schlumberger
GeoQuest

OVERFØRING AV PVT-PRØVER

FIRMA: STATIL

BRØNN: 15/9-19A

JOBBNR.: STAT 617

SIGN.: @W.

DATO: 9/9-95

PRØVETYPE: OLJE

DYBDE: _____

PVT-KAMMER NR.: REKOMBINERINGSKELLE

TIL FLASKENR.: TS-25008

REKKEFØLGE NR.: 1 AV 2

FYLLING AV FLASKE

FLASKEVOLUM: 1000 cm³

PRØVEVOLUM: 475 cm³ ved 300 barg

GLYKOL VOLUM UT FOR TRYKKSENKNING: ca. 50 cm³

GLYKOL VOLUM IGJEN I FLASKE: _____ cm³

TRYKK I FLASKE ETTER OVERFØRING: TOFASE ~~barg~~

STATUS PRØVEVOLUM I FLASKE

DATO	VOLUM UT, ENFASE	TRYKK ETTER OVERF.	SIGNATUR

Merknader:

Sjøhagen 3, Hillevåg,
4016 Stavanger.
Tlf.: 51 58 00 90

GPL

Rev. no.:

1

Date:

10.10.95

Approved, Sign.:

for

Schlumberger

GeoQuest

OVERFØRING AV PVT-PRØVER

FIRMA: STATOIL

BRØNN: 15/9-19A

JOBBNR.: STAT 617

SIGN.: O.W.

DATO: 10/9-95

PRØVETYPE: OWE

DYBDE: _____

PVT-KAMMER NR.: REKOMBINERINGSCELLE

TIL FLASKENR.: TS-23903

REKKEFØLGE NR.: _____

FYLLING AV FLASKE

FLASKEVOLUM: 1000 cm³

PRØVEVOLUM: 426.1 cm³ ved 300 barg

GLYKOL VOLUM UT FOR TRYKKSÆNKNING: ca. 50 cm³

GLYKOL VOLUM IGJEN I FLASKE: _____ cm³

TRYKK I FLASKE ETTER OVERFØRING: TOPFASE ~~-barg~~

STATUS PRØVEVOLUM I FLASKE

DATO	VOLUM UT, ENFASE	TRYKK ETTER OVERF.	SIGNATUR

Merknader:

[PROS02]SKJEMA_OVERF_PVTPROVER.OLEB