SINTEF RAPPORT

THE ENGINEERING RESEARCH FOUNDATION AT
THE NORWEGIAN INSTITUTE OF TECHNOLOGY

7034 TRONDHEIM – NTH TLF.: (075). 40120

REPORT NUMBER
STF28 F80019

AVAILABILITY
Confidential

REPORT TITLE	DATE
PVT-STUDY OF BOTTOM HOLE SAMPLE	1980-05-08
	NUMBER OF PAGES AND APP. 13
AUTHOR(S)	APPROVED
Ø. Glasø, H. Skirstad	Ola Steinsvik
DIVISION Petroleum Engineering	PROJECT NUMBER 280104.00

CLIENT	CLIENT'S REF.
STATOIL, Den norske stats oljeselskap	Per R. Thomassen

ABSTRACT

This report presents the results from a PVT-analysis performed on a bottom hole sample from 34/10-5.

SINTEF RESERVOIR FLUID STUDY

WELL: 5
FIELD: 34/10
COMPANY: STATOIL

Table Reservoir and Sample Data

Well and Formation Data

Producing zone	Statfjord
Perforation intervals	
Initial pressure	_____ psig at _____
Reservoir temperature	_____ °F at _____
Last static pressure	_____ psig at _____
Date	
Flowing pressure	_____ psig at _____
Rate (oil, water)	_____ B/D
(gas)	_____ MCF/D
Date	
Tubing size and depth	

Sample Data

Data sampled	
Type of sample(s)	Bottom Hole
Separator pressure	_____ psig
Separator temperature	_____ °F
Average flow during sampling	
First stage separator gas	_____ MCF/D
Other separator gases	_____ MCF/D
Stocktank oil	_____ B/D
Water	_____ B/D

Remarks

The bottom hole sample bottle was marked 16251/35.

SINTEF RESERVOIR FLUID STUDY

WELL: 5
FIELD: 34/10
COMPANY: STATOIL

INTRODUCTION

The present report presents the results of laboratory studies on a bottom hole sample from 34/10-5.

In the laboratory the reservoir fluid gave a bubble point pressure of 230,5 bar-g at 73.7 ^{o}C respectively 216.4 bar-g at 17.3^{o}C.

The gas-oil ratio from a single flash of the reservoir fluid in conjunction with the measured composition of the separator products was used to calculate the composition of the well stream fluid. These data are reported in Table 10.

Differential gas liberation test gave 90.1 standard cubic meter of vapor per cubic meter of residual oil. The corresponding relative volume factor was found to be 1.248 cubic meter of fluid at saturation pressure per cubic meter of residual oil.

A one-stage separation test resulted in a total GOR of 91.8 standard cubic meter of vapor per cubic meter of stock tank oil. The formation volume factor measured was 1.243 cubic meter of fluid at saturation pressure per cubic meter of stock tank oil. See Table 9 for details.

The vicosity of the liquid phase decreased form a value of 1.369 mPa·s at 400 bar, through a minimum of 1.112 mPa·s at saturation pressure and increased to a maximum of 2.930 mPa·s at atmospheric pressure during differential depletion. This is shown graphically in Figure 3.

Table 1 presents a summary of reservoir fluid properties from these studies.

SINTEF RESERVOIR FLUID STUDY

WELL: 5
FIELD: 34/10
COMAPNY: STATOIL

Table 1. Summary of Fluid Properties

1.	Bubble point pressure	230.5 bar-g at 73.7°C 216.4 bar-g at 17.3°C
2.	Density of bubble point oil	0.767
3.	Viscosity of bubble point oil	1.112 mPa·s
4.	Gas solubility of bubble point oil a. Differential gas liberation at	90.1 m^3/m^3 Resid. Oil
	b. 1-stage flash	91.8 m^3/m^3 St. Oil
5.	Relative volume factor of bubble point oil, differential test	1.248 m^3/m^3 Resid. Oil
6.	Formation volume factor of bubble point oil, 1-stage flash	1.243 m^3/m^3 St. Oil
7.	Compressibility of undersaturated reservoir oil Varies almost linearly from $0.9189 \cdot 10^{-4}$ bar^{-1} at 400 bar to $1.2559 \cdot 10^{-4}$ bar^{-1} at 240 bar.	

SINTEF RESERVOIR FLUID STUDY

WELL: 5
FIELD: 34/10
COMPANY: STATOIL

Table 3. Smoothed Constant-Composition Pressure-Volume Data at 73.7°C

Pressure bar-g	*Relative Vol. Fact. V_R*	*Y Factor*	*Compressibility (bar^{-1})*
400	0.9816		0.9189-04
380	0.9834		0.9620-04
360	0.9853		1.0048-04
340	0.9874		1.0474-04
320	0.9895		1.0897-04
300	0.9917		1.1317-04
280	0.9940		1.1734-04
260	0.9963		1.2148-04
240	0.9988		1.2559-04
230.5	1.0000	4.8445	
220	1.0100	4.7643	
200	1.0330	4.6122	
180	1.0626	4.4600	
160	1.1017	4.3079	
140	1.1545	4.1558	
120	1.2282	4.0036	
100	1.3356	3.8515	

Equations	*Pressure Range*
$Y = 3.08325 + 7.6065\ (10^{-3})p$	$100.0 < p < 230.5$
$V_R = 1.03543 - 1.7852\ (10^{-4})p + 1.1013(10^{-7})p^2$	$230.5 < p < 400.0$
$V_R = \frac{231.5 + 2.08325 + 7.6065(10^{-3})p^2}{3.08325p + 7.6065(10^{-3})p^2}$	$100.0 < p < 230.5$
$C_o = \frac{1.7852(10^{-4}) - 2.2026(10^{-7})p}{1.03543 - 1.7852(10^{-4})p + 1.1013(10^{-7})p^2}$	230.5 p 400.0

Pressures in the above equations are in bar-absolute.

SINTEF RESERVOIR FLUID STUDY

WELL: 5
FIELD: 34/10
COMPANY: STATOIL

Table 5. Smoothed Liquid and Gas Viscosity Data at 73.7°C

Pressure bar-g	*Liquid Phase Viscosity mPa·s*	*Gas Phase Viscosity mPa·* *)*
400	1.369	
380	1.339	
360	1.309	
340	1.278	
320	1.248	
300	1.217	
280	1.187	
260	1.157	
240	1.126	
230.5	1.112	
220	1.114	1.8250-02
200	1.141	1.7441-02
180	1.185	1.6610-02
160	1.248	1.5849-02
140	1.329	1.5126-02
120	1.429	1.4443-02
100	1.547	1.3799-02

Equations	*Pressure Range*
$\mu_o = 7.61833(10^{-1}) + 1.51859(10^{-3})p$	$230.5 < p < 400$
$\mu_o = 2.40891 - 1.09064(10^{-2})p + 2.28277(10^{-5})p^2$	$100 < p < 230.5$
$\mu_o = 1.11633(10^{-2}) + 2.14680(10^{-5})p + 4.88476(10^{-8})p^2$	$100 < p < 230.5$

*) Calculated from gas gravity and data of Carr, Kobyashi and Burrows.

Pressures in the above equations are in bar-gage.

SINTEF RESERVOIR FLUID STUDY

WELL: 5
FIELD: 34/10
COMPANY: STATOIL

Table 6. Experimental Constant-Composition Pressure-Volume Data at 73.7°C

Pressure psig	*Relative Vol.Fact.* V_R	*Y Factor*
392.8	0.9823	
344.7	0.9870	
295.7	0.9923	
270.2	0.9952	
246.6	0.9980	
236.8	0.9994	
230.5	1.0000	
228.0	1.0024	4.5568
218.2	1.0117	4.8362
197.6	1.0346	4.7941
172.6	1.0745	4.4845
147.6	1.1318	4.2353
118.7	1.2415	3.8729

SINTEF RESERVOIR FLUID STUDY

WELL: 5
FIELD: 34/10
COMPANY: STATOIL

Table 7. Experimental Liquid Phase Viscosity Data at 73.7°C

Pressure bar-g	*Liquid Phase Viscosity, mPa·s*
388.4	1.355
349.1	1.285
299.1	1.220
251.1	1.145
237.3	1.120
220.7	1.115
208.9	1.130
191.2	1.150
170.6	1.215
150.0	1.285
122.6	1.420
92.2	1.595
61.1*	1.862
0 *	2.930

*) Not used in equation fit.

WELL: 5
FIELD: 34/10
COMPANY: STATOIL

Table 8. Experimental Differential Gas Liberation Data at 73.7°C

Pressure bar-g	*Liberated Gas-Oil Ratio m^3/m^3 Residual Oil*	*Solution Gas-Oil Ration m^3/m^3 Residual Oil*	*Relative Volume m^3/m^3 Residual Oil*	*Saturated Oil Density g/cm^3*	*Compressibility Factor of Liberated Gas Z*	*Average Gravity of Liberated Gas (air=1)*
230.5		90.1	1.248	0.767		
206.4	8.9	81.2	1.231	0.772	-	0.610
184.9	17.4	72.7	1.214	0.778	0.904	0.603
161.3	26.0	64.1	1.196	0.784	0.906	0.595
139.7	33.9	56.2	1.180	0.789	0.909	0.593
116.2	42.7	47.4	1.162	0.797	0.914	0.592
93.7	51.1	39.0	1.144	0.803	0.926	0.595
69.1	60.4	29.7	1.125	0.812	0.952	0.604
47.6	68.3	21.8	1.108	0.818	0.962	0.624
23.0	77.8	12.3	1.087	0.826	0.985	0.680
0	90.1		1.052	0.840	1.000	1.006
		at 15.0°C	1.000			

Residual oil specific gravity = 0.884 g/cm^3 at 15.0°C

Average gravity of total liberated gas = 0.665

Notes:

(1) Reservoir fluid bubble point pressure is 230.5 bar-g at 73.7°C.

(2) Gas/oil ratios are cubic meter of gas at 1.013 bar and 15.0°C per cubic meter of residual oil at 1.013 bar and 15.0°C.

(3) Relative oil volumes are cubic meter of saturated reservoir oil per cubic meter residual oil at 1.013 bar and 15.0°C.

SINTEF RESERVOIR FLUID STUDY

WELL: 5
FIELD: 34/10
COMPANY: STATOIL

Table 9. Separator Tests of Reservoir Fluid Sample

	Separator pressure, bar
	1.013
Separator temperature, ^{o}C	15
Separator gas/oil ration, m^3/m^3	91.8
Separator gas gravity, air = 1	0.662
Stocktank oil gravity, g/cm^3	0.883
Bubble point formation volume factor, m^3/m^3	1.243

Notes:

(1) Gas and liquid volumes are expressed at standard conditions of 1.013 bar and 15.0^{o}C.

(2) Reservoir fluid bubble point pressure is 230.5 bar-g at 73.7^{o}C.

(3) Gas/oil ratios are standard cubic meter of gas per cubic meter of stocktank oil.

SINTEF RESERVOIR FLUID STUDY

WELL: 5
FIELD: 34/10
COMPANY: STATOIL

Table 10. Analysis of Separator Streams from Single Flash and Calculated Reservoir Fluid Composition

	Mole Fraction		
Component	*Separator Gas*	*Separator Liquid*	*Reservoir Fluid*
Carbon dioxide	0.0100		0.0051
Nitrogen	0.0072		0.0037
Methane	0.8562		0.4347
Ethane	0.0709	0.0039	0.0379
Propane	0.0114	0.0016	0.0066
iso-Butane	0.0074	0.0028	0.0054
n-Butane	0.0061	0.0032	0.0047
iso-Pentane	0.0067	0.0065	0.0066
n-Pentane	0.0018	0.0026	0.0022
Hexanes	0.0064	0.0142	0.0102
Heptanes	0.0155	0.0546	0.0347
Octanes		0.0964	0.0475
Nonanes		0.0736	0.0362
Decanes		0.0744	0.0366
Undecanes plus		0.6662	0.3279
	1.000	1.0000	1.0000

Properties of Heneicosanes plus

Molecular weight	297.5	
Specific gravity	0.914	15.0/15.0°C = 23.31°API

Properties of Stock Tank Oil

Molecular weight	235.1	
Specific gravity	0.883	15.0/15.0°C = 28.75°API

SINTEF RESERVOIR FLUID STUDY

WELL: 5
FIELD: 34/10
COMPANY: STATOIL

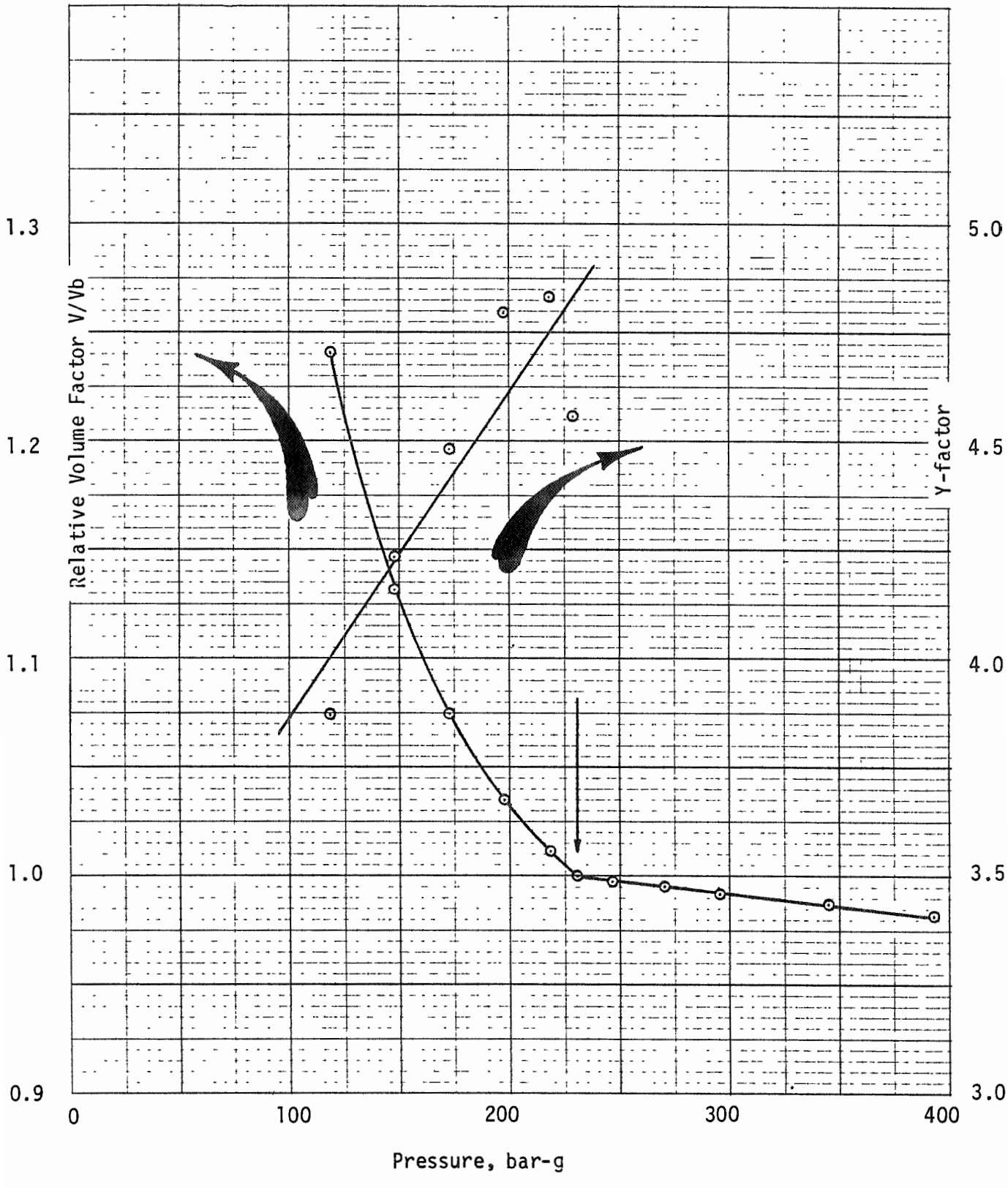

Figure 1. Experimental constant-composition pressure-volume and Y factor vs. pressure. Temperature 73.7°C.

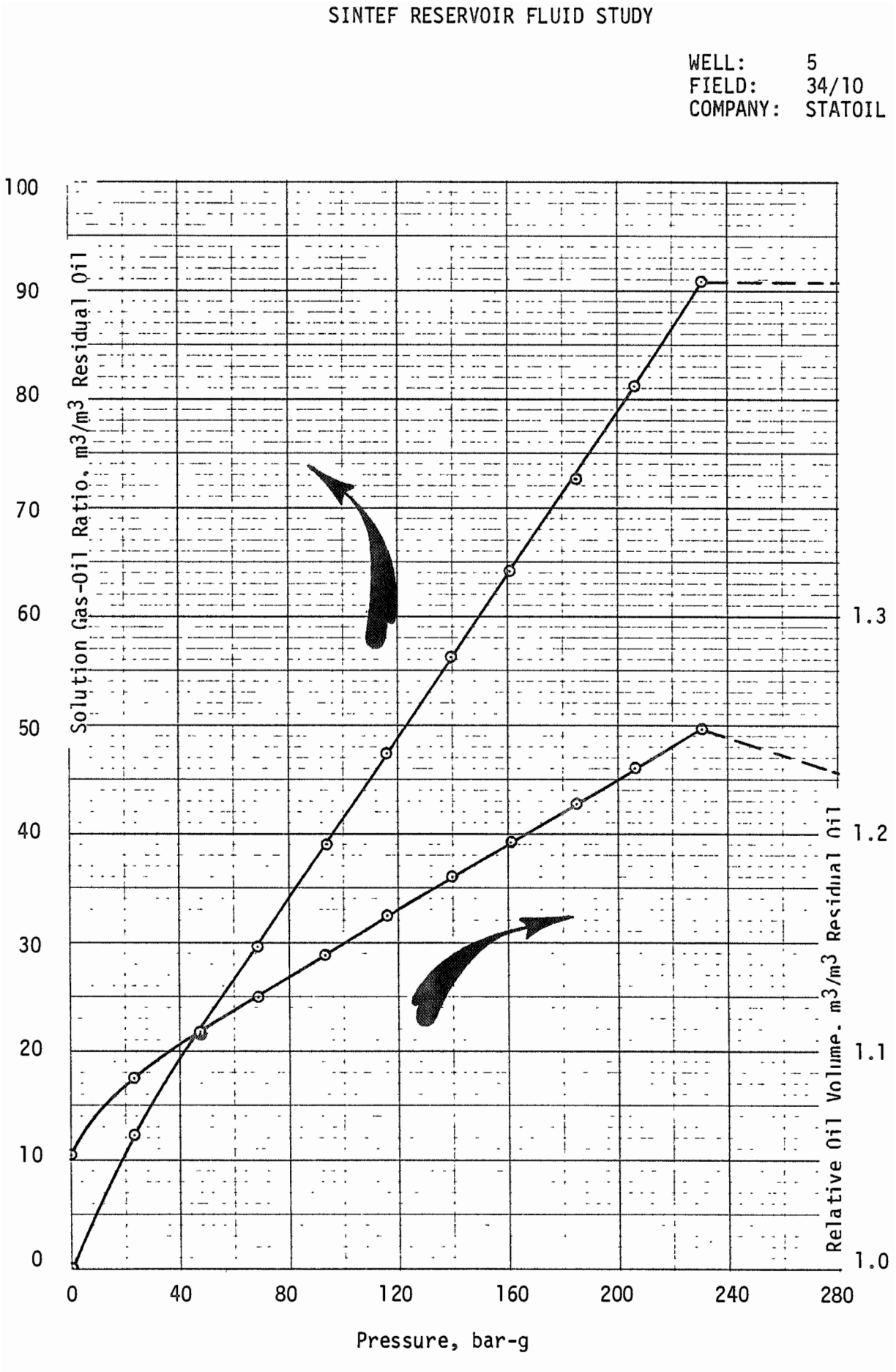

Figure 2. Experimental gas solubility and relative oil volume data vs. pressure. Differential gas liberation process. Temperature 73.7°C.

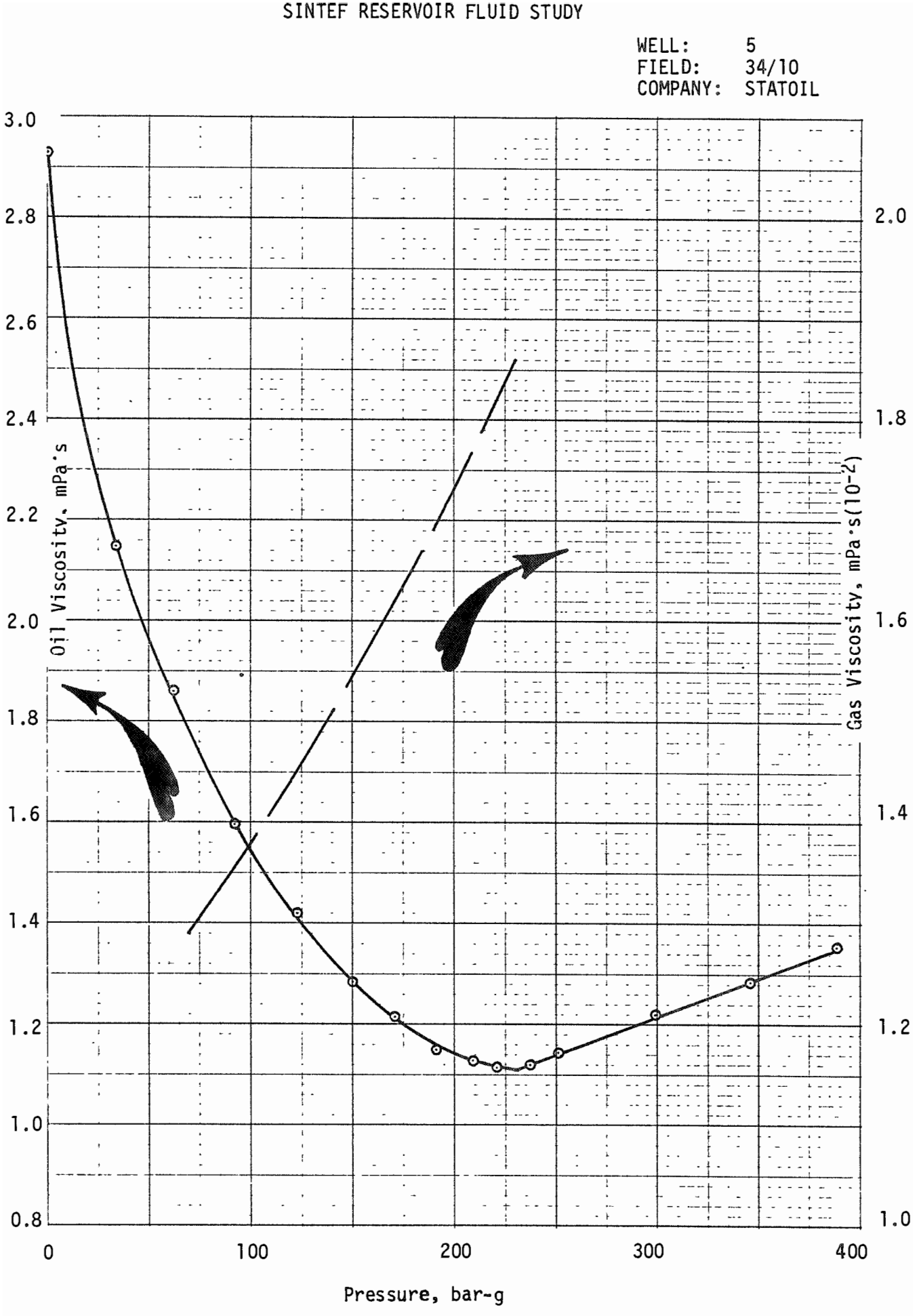

Figure 3. Experimental oil viscosity and calculated gas viscosity vs. pressure. Temperature 73,7°C.