RESERVOIR FLUID STUDY

FORTROLIG

i h.t. Beskyttelsesinstruksen,
jfr. offentlighetslovens
§............ nr.................

FOR

STATOIL

DEN NORSKE STATS OLJESELSKAP A/S

Stavanger, Norway

BOTTOM HOLE SAMPLE

OIL WELL NO 34/10-3

DST NO 2

SINTEF

PETROLEUM ENGINEERING DIVISION
THE FOUNDATION OF SCIENTIFIC AND INDUSTRIAL
RESEARCH AT THE UNIVERSITY OF TRONDHEIM

SINTEF RAPPORT

THE ENGINEERING RESEARCH FOUNDATION AT
THE NORWEGIAN INSTITUTE OF TECHNOLOGY

REPORT TITLE	DATE
	1979-09-05
PVT-STUDY OF BOTTOM HOLE SAMPLE	NUMBER OF PAGES AND APP. 10+3
AUTHOR(S)	APPROVED
H. Skirstad	*O. Stiimst*
DIVISION Petroleum Technology	PROJECT NUMBER 280.071.00

CLIENT	CLIENT'S REF.
STATOIL	Per R. Thomassen

ABSTRACT

This report presents the results from a PVT-analysis performed
on a bottom hole sample from field 34/10, well 3.

SINTEF RESERVOIR FLUID STUDY

INTRODUCTION

The present report presents the results of laboratory studies on a bottom hole sample from field 34/10, well 3.

In the laboratory the reservoir fluid gave a bubble point pressure of 218.3 bar at 346.45°K respectively 190.3 bar at 290.55°K.

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 9.

Differential gas liberation test gave 79.2 standard cubic meter of vapor per cubic meter of residual oil. The corresponding relative volume factor was found to be 1.226 cubic meter of fluid at saturation pressure per cubic meter of residual oil.

A one-stage test separation resulted in a total GOR of 81.6 standard cubic meter of vapor per cubic meter of stock tank oil. The formation volume factor measured was 1.230 cubic meter of fluid at saturation pressure per cubic meter of stock tank oil. See Table 8 for details.

The viscosity of the liquid phase decreased from a value of 1.706 mPa·s at 400 bar, through a minimum of 1.317 mPa·s at saturation pressure and increased to a maximum of 3.150 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

Table 1.   Summary of Fluid Properties

1. Bubble point pressure

218.3 bar at 346.45^{O}K
190.3 bar at 290.55^{O}K

2. Density of bubble point oil

0.7723 gm/cc

3. Viscosity of bubble point oil

1.317 mPa·s

    a. Differential gas liberation at
       346.45^{O}K

79.2 m^3/m^3

    b. 1-stage flash

81.6 m^3/m^3

5. Relative volume factor of bubble point
    oil, differental test

1.226 m^3/m^3

6. Formation volume factor of bubble point
    oil, 1-stage flash

1.230 m^3/m^3

7. Compressibility of undersaturated
    reservoir oil

Varies almost linearly from $8.99 \cdot 10^{-5}$ bar^{-1} at 400 bar to $12.52 \cdot 10^{-5}$ bar^{-1} at 220 bar.

SINTEF RESERVOIR FLUID STUDY

Table 2. Reservoir and Sample Data

Well and Formation Data

Producing zone	
Perforation intervals	1935/40 m
Initial pressure	_____ psig at _____
Reservoir temperature	346.45 ^{o}K at _____
Last static pressure	_____ psig at _____
Date	
Flowing pressure	_____ psig at _____
Rate (oil, water)	B/D
(gas)	MCF/D
Date	
Tubing size and depth	$3\frac{1}{2}$" D.P.

Sample Data

Data sampled	1979-05-31
Type of sample(s)	Bottom Hole
Separator pressure	psig
Separator temperature	^{o}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 20584/96.

Table 3.   Smoothed Constant-Composition Pressure-Volume Data at 346.45°K

Pressure bar	Relative Vol. Fact. V_R	Y Factor	Compressibility (bar^{-1})
400	0.9805		0.8994-04
380	0.9823		0.9395-04
360	0.9842		0.9794-04
340	0.9862		1.0191-04
320	0.9882		1.0585-04
300	0.9904		1.0976-04
280	0.9916		1.1365-04
260	0.9949		1.1751-04
240	0.9972		1.2135-04
220	0.9997		1.2515-04
218.3	1.0000	4.7348	
200	1.0201	4.5430	
180	1.0491	4.3333	
160	1.0884	4.1236	
140	1.1429	3.9190	
120	1.2211	3.7042	
100	1.3385	3.4945	

Equations	Pressure range
$Y = 2.44601 + 1.04848\,(10^{-2})p$	$100.0 < p < 218.3$
$V_R = 1.03220 - 1.70245\,(10^{-4})p + 1.02570(10^{-7})\,p^2$	$218.3 < p < 400.0$
$V_R = \dfrac{218.3 + 1.44601p + 1.04848(10^{-2})p^2}{2.44601p + 1.04848(10^{-2})p^2}$	$100.0 < p < 218.3$
$C_o = \dfrac{1.70245(10^{-4}) - 2.05140(10^{-7})p}{1.03220 - 1.70245(10^{-4})p + 1.02570(10^{-7})p^2}$	$218.2 < p < 400.0$

Table 4.   Smoothed Liquid and Gas Viscosity Data at 346.45°K

Pressure bar	Liquid Phase Viscosity-mPa·s	Gas Phase Viscosity-mPa·s *)
400	1.704	
380	1.661	
360	1.618	
340	1.576	
320	1.534	
300	1.491	
280	1.448	
260	1.406	
240	1.363	
220	1.321	
218.3	1.317	
200	1.327	2.4006-02
180	1.346	2.2224-02
160	1.392	2.0548-02
140	1.467	1.8979-02
120	1.569	1.7516-02
100	1.700	1.6160-02
80	1.860	1.4911-02
60	2.047	1.3768-02

Equations	Pressure range
$\mu_0 = 0.851791 + 0.213059(10^{-2})p$	$218.3 < p < 400.0$
$\mu_0 = 2.777231 - 1.428606(10^{-2})p + 3.518169(10^{-5})p^2$	$60.0 < p < 218.3$
$\mu_0 = 0.1097911(10^{-1}) + 3.849012(10^{-5})p + 1.332202(10^{-7})p^2$	$60.0 < p < 218.3$

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

SINTEF RESERVOIR FLUID STUDY

Table 5. Experimental Constant-Composition Pressure-Volume Data at 346.45^{O}K

Pressure bar	Relative Vol. Fact. V_R	Y Factor
348.7	0.9853	
299.6	0.9904	
250.6	0.9960	
225.6	0.9989	
218.3	1.0000	
210.4	1.0094	3.9754[*]
189.8	1.0344	4.3631
174.1	1.0585	4.3333
150.6	1.1114	4.0332
125.1	1.1971	3.7792
100.5	1.3335	3.5113
75.1	1.5927	3.2172
57.4	1.9231	3.0338

[*]Not used in equation fit.

Table 6. Experimental Liquid Phase Viscosity Data at 346.45$^{\text{o}}$K

Pressure bar	Liquid Phase Viscosity, mPa·s
366.3	1.635
306.5	1.510
286.9	1.460
272.2	1.420
249.6	1.380
226.6	1.345
204.5	1.325
178.0	1.355
156.5	1.400
130.0	1.510
109.4	1.640
77.0	1.885
37.8	2.330
1.0	3.150

Table 7. Experimental Differential Gas Liberation Data at 346.45°K

Pressure bar	Liberated Gas-Oil Ratio m³/m³ Residual Oil	Solution Gas-Oil Ratio m³/m³ Residual Oil	Relative Volume m³/m³ Residual Oil	Saturated Oil Density gm/cc	Compressibility Factor of Liberated Gas Z*	Average Gravity of Liberated Gas (air=1)
218.3	-	79.2	1.2262	0.7723	-	-
198.6	7.2	72.0	1.2101	0.7780	0.864	0.626
179.7	13.6	65.5	1.1956	0.7834	0.862	0.615
159.4	20.0	59.1	1.1814	0.7888	0.863	0.611
140.3	26.7	52.4	1.1670	0.7943	0.870	0.609
120.7	33.1	46.0	1.1516	0.8007	0.882	0.610
97.1	41.9	37.3	1.1327	0.8083	0.892	0.613
73.6	50.3	28.9	1.1144	0.8153	0.912	0.620
50.0	59.3	19.9	1.0962	0.8231	0.943	0.632
26.5	68.3	10.9	1.0771	0.8306	0.982	0.693
1.0	79.2	-	1.0512	0.8390		0.948
		288.15°K	1.0000			

Residual oil specific gravity = 0.8821 at 288.15°K = 28.9°API

Average gravity of total liberated gas   = 0.6715

*Calculated from average gas gravity and correlation of Standing and Katz.

NOTES:

(1) Reservoir fluid bubble point pressure is 218.3 bar at 346.45°K.

(2) Gas/oil ratios are cubic meter of gas at 1.013 bar and 288.15°K per cubic meter of residual oil at 1.013 bar and 288.15°K.

(3) Relative oil volumes are cubic meter of saturated reservoir oil per cubic meter residual oil at 1.013 bar and 288.15°K.

SINTEF RESERVOIR FLUID STUDY

Table 8.   Separator Tests of Reservoir Fluid Sample

Separator pressure, bar

1.013

Separator temperature, $^{\circ}K$	288.15
Separator gas/oil ratio, m^3/m^3	81.6
Separator gas gravity, air = 1	0.6726
Stocktank oil gravity, $^{\circ}API$	28.8
Bubble point formation volume factor, m^3/m^3	1.230

Notes:

(1) Gas and liquid volumes are expressed at standard conditions of 1.013 bar and 288.15$^{\circ}K$.

(2) Reservoir fluid bubble point pressure is 218.3 bar at 346.45$^{\circ}K$

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

Table 9. Analysis of Separator Streams from Single Flash and Calculated Reservoir Fluid Composition

	Mole Fraction		
Component	Separator Gas	Separator Liquid	Reservoir Fluid
Carbon dioxide	0,0106		0,0049
Nitrogen	0,0098		0,0045
Methane	0,8460		0,3954
Ethane	0,0689	0,0037	0,0342
Propane	0,0138	0,0015	0,0073
iso-Butane	0,0068	0,0046	0,0056
n-Butane	0,0040	0,0023	0,0031
iso-Pentane	0,0057	0,0087	0,0073
n-Pentane	0,0008	0,0034	0,0020
Hexanes	0,0078	0,0334	0,0210
Heptanes	0,0258	0,0484	0,0377
Octanes		0,0900	0,0483
Nonanes		0,0715	0,0383
Decanes		0,0716	0,0382
Undecanes plus.		0,6609	0,3520
	1.0000	1.0000	1.0000

Handwritten annotations:
M / u-P
Heptanes 100.198 0.68819
Octanes 114.224 0.70677
Nonanes 128.250 0.72171
Decanes 142.276 0.73413
49.78

Sammensetning er ikke korrekt! Sjå korr. senere

Properties of Undecanes plus

Molecular weight 283.4
Specific gravity 0,917   288,15/288,15°K = 22,81° API

Properties (calc.) C$_{7+}$
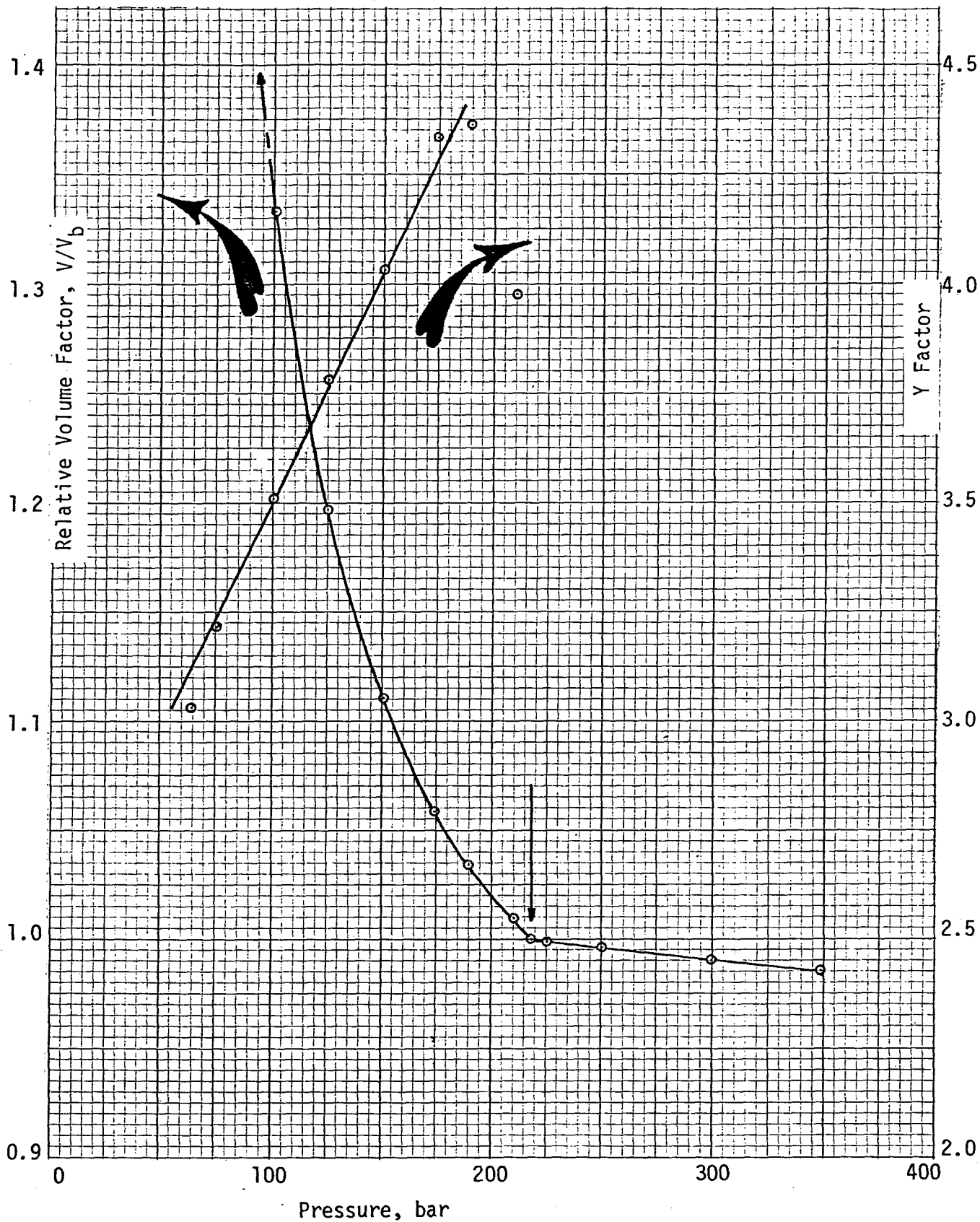
M = 239.85
ρ = 0.881 = 29.11 $^\circ$API

SINTEF RESERVOIR FLUID STUDY

Figure 1. Experimental constant-composition pressure-volume and Y factor
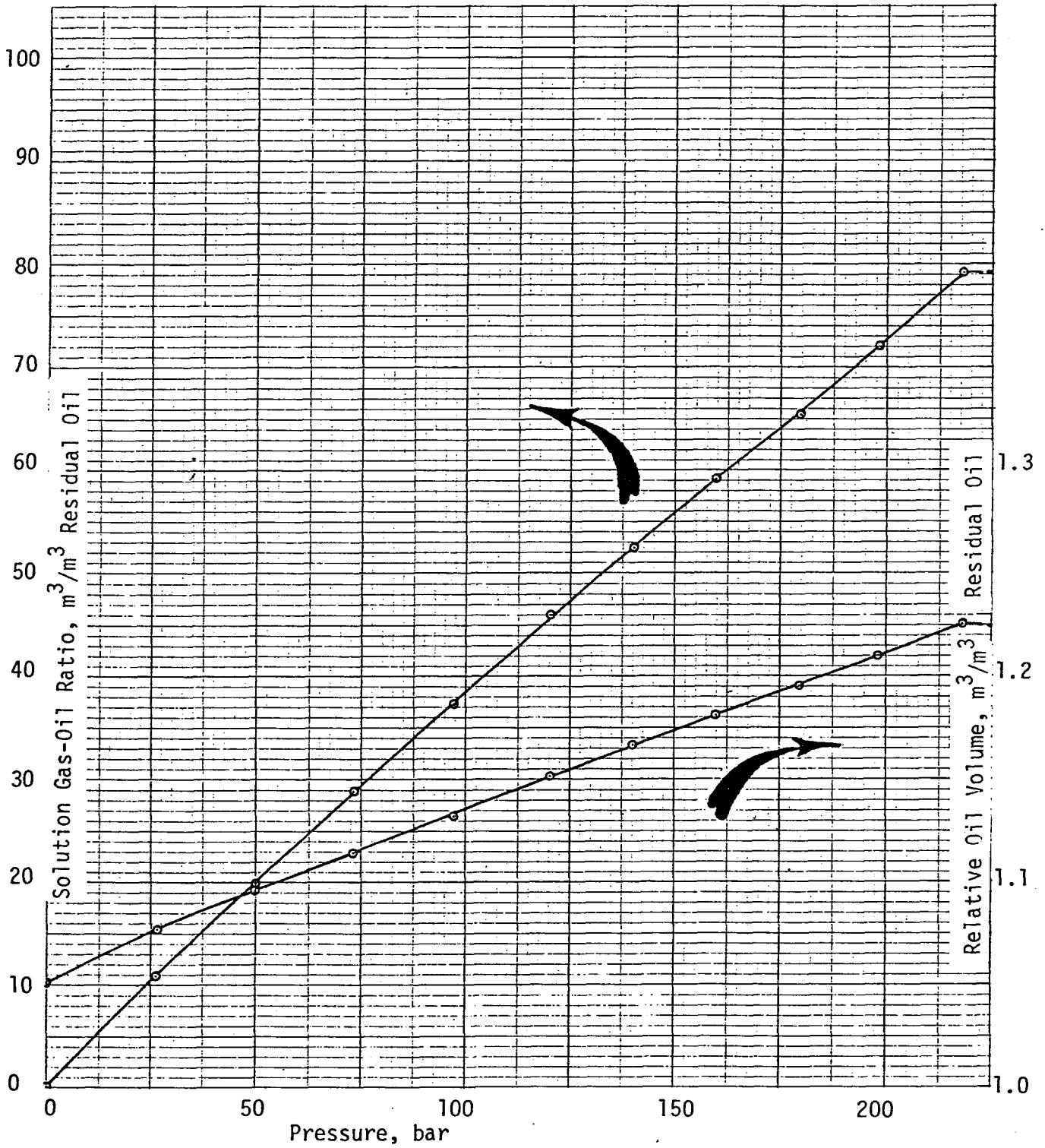vs. pressure. Temperature 346.45°K.

Figure 2. Experimental gas solubility and relative oil volume data vs. pressure.
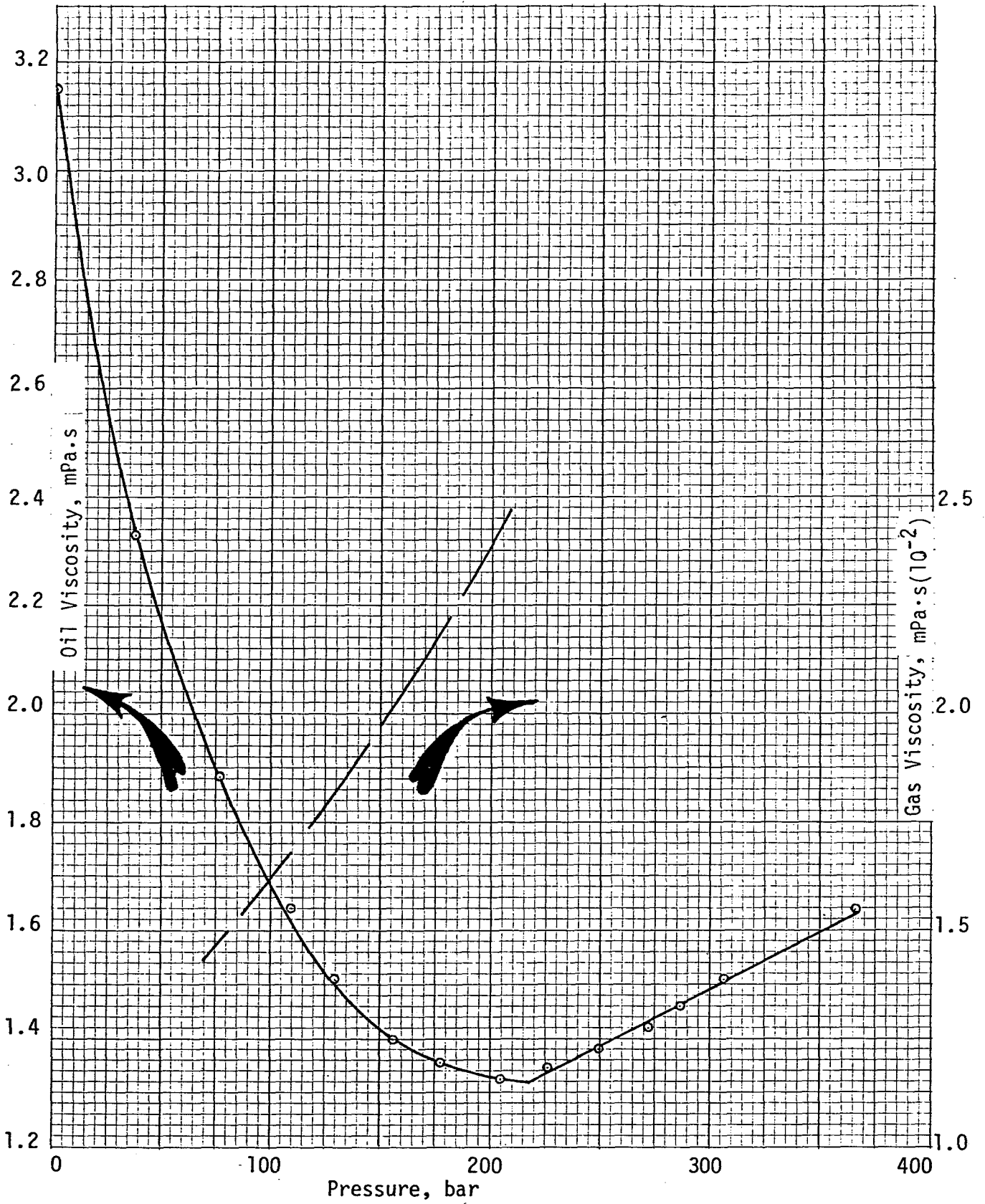Differential gas liberation process. Temperature 346.45°K.

SINTEF RESERVOIR FLUID STUDY

Figure 3.   Experimental oil viscosity and calculated gas viscosity vs.
            pressure. Temperature 346.45°K.

N O T A T

TIL: JHa

FRA: PT/PROLAB

SAK: SINTEF PVT   REPORT 34/10-3 280.071.00

Upon receiving the above mentioned report it was noted that
the composition of separator gas given in table 9 obviously
was incorrect. A gas phase C_7+ concentration of 2.6% are
unlikely to occur in other than gas condensate systems.

This was pointed out to Sintef, who immediately realised
the mistake and reported back a new composition in letter of
29.9.79. The reason for the mistake was that the engineer
had forgotten to apply responsefactor to the C_7+ group.

Gas Z-factor reported from the differential study in table 7
are not obtained experimentally. A correlation was used
because experimental data did not yield useable   values for
Z-factor.

Ø. Glasø
Avd. 28, SINTEF

7034 TRONDHEIM/NTH

Deres ref. Your ref.	Deres brev av Your letter of	Vår ref. Our ref. PT/MTL	Dato Date 23.7.79

SAK: PVT-STUDIE 34/10-3, BHS DST 2.

Ett "bottom hole sample" (No. 20584/96) ble sendt Dem pr.
·linjegods i dag, 23.7.79.

Vi ønsker følgende analyser utført på denne prøve:

1. Kokepunkt til prøven i transport beholder ved romtemperatur.

2. Kokepunkt til prøven ved $73.3^{o}C$ ($164^{o}F$) tilsvarende service
   2.4 i prislisten.

3. Ett stegs flash av reservoar væske til 1 atm og $15^{o}C$ som
   service 2.8 i prislisten.

4. Diff lib. tilsvarende service 2.5.

5. Viskositet til reservoar væske ved reservoar temperatur
   tilsvarende service 2.7.

6. Komposisjonsanalyse.

   Komposisjonen til reservoarvæsken angis med reelle komp-
   onenter til og med nC_5 deretter og frem til $C_{11}+$(ekvivalent
   kokepunkt $174,6^{o}C$ ved 1 atm) gruppens komponenter etter
   metode beskrevet av Katz, D.L. og Firoozabadi A; (JPT vol
   xx, no 11, pp 1649). For hver gruppe angis den relative
   fordeling av naftenske, parafinske og aromatiske forbin-··
   delser. For C_{11} + fraksjon bestemmes eksperimentelt tett-
   het, molekylvekt og den relative fordeling av naftenske,
   parafinske og aromatiske forbindelser.

   Rapportering:

   Det må framgå hvilke resultat som er bestemt eksperimentelt
   og hva som er beregnet. Alle målte resultat, inkludert
   kromatogram ønskes vedlagt rapporten.

SI enheter skal benyttes (unntatt for trykk hvor bar benyttes) med standard referanse betingelser definert som 1.013 bar og 15°C.

Resultatene angis med gjeldende siffer og usikkerhetene oppgis hvor dette er kjent.

En representant fra Produksjonslaboratoriet vil være tilstede ved deler av analysen.

Statoil's kontaktpersoner i perioden 23/7 - 13/8 vil være Arne M. Martinsen tlf. (045) 77251.

Med hilsen
for Den norske stats oljeselskap a.s

Karl Sigurd Årland

SINTEF

THE FOUNDATION OF SCIENTIFIC AND INDUSTRIAL RESEARCH AT THE NORWEGIAN INSTITUTE OF TECHNOLOGY

STATOIL
Lagardsvegen 78

4000 STAVANGER

Attn.: Mr. P.Thomassen

Trondheim, 1979-09-07
Our ref.: 571+2/79/ØG/ub

COMMENTS TO CHROMATOGRAPHIC ANALYSIS OF STOCK TANK GAS AND STOCK TANK OIL, WELL 34/10-3.

The amount of n-paraffinic hydrocarbons in the separator gas are much less than what have been found in samples from other North Sea reservoirs. (ref. composition of the stock tank gas, table 3.)

Iso-paraffinic, naphtenic and aromatic hydrocarbons are dominating related to n-paraffinic hydrocarbons in the stock tank liquid.

The concentrations are expressed as weight percent of the total mixture of $C_{11}+$ from fractional destillation :

Paraffins + naphtens	:	53,3 %
Aromats	:	38,8 %
Sum		92,1 %

The residue (7,9 weight percent) is supposed to represent sediments and kerogens.

Experimental determined specific gravity and molecular weight of the $C_{11}+$ fraction gave the following results:

Specific gravity	:	0,9053
Molecular weight	:	283,4

The distribution of naphtenic, aromatic and paraffinic hydrocarbons in each fraction from C_6 through C_{11} have not been performed as the equipment needed for this kind of studies are not available at time being. This equipment will be ordered as soon as possible.

The accuracy of the PVT-measurements are in general assumed to be ± 1 relative percent, but for the compressibility factor based on specific gravity of the gas, we assume the accuracy to be ± 2-5 relative percent.

Regards,

Helge Skirstad
Engineer
Department of Petroleum Technology

SINTEF

SELSKAPET FOR INDUSTRIELL OG TEKNISK
FORSKNING VED NORGES TEKNISKE HØGSKOLE

Postadresse:
7034 Trondheim — NTH

Telefon:
(075) 93000*

Telex:
55186 NTHB N. SINTEF

STATOIL
Postboks 300
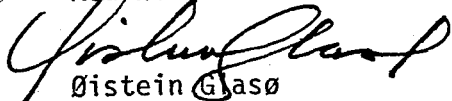4001 Stavanger

Att.: Siv.ing. Per Thomassen

Trondheim, 1979-09-27
Vår ref.: 280071/79/ØG/bsv

PVT-ANALYSE, BRØNN 34/10-3, DST 2

Det vises til telefonsamtale med Per Thomassen 24. sept. d.å. angående feil i kromatografisk analyse av separatorgassen fra ovennevnte brønn.

./. Vi sender herved en korrigert komposisjonsanalyse (tabell 9 i rapporten).

Med hilsen

Øistein Glasø
Forsker

VEDLEGG: Korrigert tabell 9.

SINTEF RESERVOIR FLUID STUDY

Table 9. Analysis of Separator Streams from Single Flash and Calculated Reservoir Fluid Composition

Component	Mole Fraction		
	Separator Gas	Separator Liquid	Reservoir Fluid
Carbon dioxide	0.0106		0.0050
Nitrogen	0.0098		0.0046
Methane	0.8631		0.4032
Ethane	0.0703	0.0037	0.0348
Propane	0.0141	0.0015	0.0074
iso-Butane	0.0068	0.0046	0.0057
n-Butane	0.0041	0.0023	0.0031
iso-Pentane	0.0058	0.0087	0.0074
n-Pentane	0.0008	0.0034	0.0020
Hexanes	0.0080	0.0334	0.0215
Heptanes	0.0065	0.0484	0.0287
Octanes		0.0900	0.0481
Nonanes		0.0715	0.0381
Decanes		0.0716	0.0382
Undecanes plus.		0.6609	0.3522
	1.0000	1.0000	1.0000

Handwritten reservoir fluid column annotations: 0.0099 (or C.0.99), 0.0005, 0.4351, 0.6362, 6.0061, 0.0069, 0.0041, 0.0072, 0.0012, 0.0064, 0.0362, 4716 (84.4476)

Handwritten: 50.95

Properties of Undecanes plus

Molecular weight	293.4	
Specific gravity	0.917	$288,15/288,15\ °K = 22,81°$ API