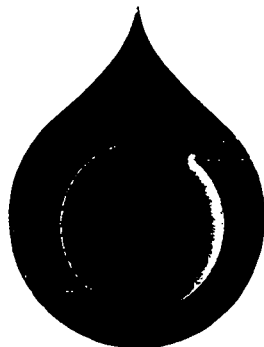


# RESERVOIR FLUID STUDY



Denne rapport  
tilhører

 **STATOIL**

L&U DOK.SENTER

L.NR. 30287290049

KODE Well 31/2-3 nr 59

Returneres etter bruk

FOR

## A/S NORSKE SHELL EXPLORATION & PRODUCTION

BOTTOM HOLE SAMPLE

WELL NO 31/2 - 3

# SINTEF

DIVISION OF PETROLEUM TECHNOLOGY

N-7034 TRONDHEIM-NTH, NORWAY

TELEPHONE: (075) 92 854

TELEX: 55186 NTHB N, SINTEF

COMMENTS TO SINTEF's PVT STUDY ON A 31/2-3 OIL SAMPLE

The report on the above study was not issued to partners subsequent to receipt by Norske Shell. The reason was discussions with SINTEF on details in the report. Firstly the oil viscosity appears to be considerably lower than was found from another sample analysed by Statoil. Secondly, the bubble point of the recombined sample was some 20 psi lower than specified by Norske Shell. Thirdly the separator test was performed on the bottom hole sample prior to, instead of subsequent to, recombination with additional gas as specified by Norske Shell.

However, SINTEF was not willing to admit any mistakes and the report is therefore presented in its original form.

B. Reinholdt

Han har nok rett i at oljeviskositeten rapportert her er for lav. Det at kokepunktet er for lavt med 20 psi har ikke noe praktisk betydning.

Følgelig ikke noe stort på den reservoar komposisjonen som er rapportert her, da vi har dårlige erfaringer med SINTEF på dette punkt.

Den siste kommentar til Bjørn beskriver er nok så typisk for de reaksjoner en vil få om man prøver å fortelle de at de har gjort feil.

Per Thomsen

N-7034 TRONDHEIM - NTH

TELEPHONE: (47) (075) 93000  
TELEX: 55186 NTHB N SINTEF

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PROJECT CLIENT/SPONSOR  A/S Norske Shell Exploration & Production	CLIENT'S REF.  B. Reinholdtsen
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EXTRACT  This report present the result from a PVT-analyses performed on a bottom hole sample from well 31/2-3.
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SINTEF RESERVOIR FLUID STUDY

WELL : 31/2-3  
 COMPANY : Norske Shell A/S

Table 3. Smoothed Constant-Composition Pressure-Volume Data at 160 °F

Pressure psig	Relative Vol. Fact. $V_R$	Y Factor	Compressibility (psi <sup>-1</sup> )
4000	0.9879		0.6650-05
3800	0.9892		0.6737-05
3600	0.9905		0.6823-05
3400	0.9919		0.6909-05
3200	0.9933		0.6995-05
3000	0.9947		0.7080-05
2800	0.9961		0.7165-05
2600	0.9975		0.7249-05
2400	0.9990		0.7333-05
<u>2261</u>	1.0000	4.7224	
2200	1.0059	4.6721	
2000	1.0287	4.5056	
1800	1.0585	4.3391	
1600	1.0980	4.1726	
1400	1.1518	4.0061	
1200	1.2274	3.8396	
1000	1.3382	3.6731	
800	1.5112	3.5066	
600	1.8088	3.3401	

Equations	Pressure range
$Y = 2.82835 + 0.83249(10^{-3})p$	$600 \leq p \leq 2261$
$V_{R1} = 1.01804 - 0.84675(10^{-5})p + 0.23642(10^{-9})p^2$	$2261 \leq p \leq 4000$
$V_{R2} = \frac{2275.0 + 1.82835p + 0.83249(10^{-3})p^2}{2.82835p + 0.83249(10^{-3})p^2}$	$600 \leq p \leq 2261$
$C_o = \frac{0.84675(10^{-5}) - 0.47284(10^{-9})p}{1.01804 - 0.84675(10^{-5})p + 0.23642(10^{-9})p^2}$	$2261 \leq p \leq 4000$

Pressures in the above equations are in psia.

SINTEF RESERVOIR FLUID STUDY

WELL : 31/2-3  
 COMPANY : Norske Shell A/S

Table 4. Smoothed Liquid and Gas Viscosity Data at 160 °F

Pressure psig	Liquid Phase Viscosity-cp.	Gas Phase Viscosity-cp.*
4000	2.194	
3800	2.153	
3600	2.111	
3400	2.069	
3200	2.028	
3000	1.986	
2800	1.944	
2600	1.902	
2400	1.861	
2261	1.838	
2200	1.856	0.016372
2000	1.885	0.015799
1800	1.938	0.015255
1600	2.015	0.014742
1400	2.115	0.014258
1200	2.239	0.013805
1000	2.387	0.013381
800	2.559	0.012987
600	2.755	0.012624
400	2.974	0.012290

Equations	Pressure range
$\mu_{o1} = 1.36032 + 0.208514(10^{-3})p$	$2261 \leq p \leq 4000$
$\mu_{o2} = 3.48492 - 0.139543(10^{-2})p + 0.297799(10^{-6})p^2$	$400 \leq p \leq 2261$
$\mu_g = 1.17123(10^{-2}) + 0.129429(10^{-5})p + 0.374514(10^{-9})p^2$	$400 \leq p \leq 2261$

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

Pressures in the above equations are in psig.

SINTEF RESERVOIR FLUID STUDY

WELL : 31/2-3  
 COMPANY : Norske Shell A/S

Table 5. Experimental Constant-Composition Pressure-Volume Data at 160 °F

<i>Pressure psig</i>	<i>Relative Vol.Fact. <math>V_R</math></i>	<i>Y Factor</i>
4258	0.9860	
3547	0.9906	
2836	0.9957	
2410	0.9987	
2268	0.9998	
<u>2261</u>	1.0000	
2175	1.0073	5.3397*
2054	1.0220	4.5233
1763	1.0656	4.2674
1443	1.1341	4.1836
1038	1.3201	3.6308

\* Not used in equation fit.

**SINTEF RESERVOIR FLUID STUDY**

WELL : 31/2-3

COMPANY : Norske Shell A/S

**Table 6. Experimental Differential Gas Liberation Data at 160 °F**

Pressure psig	Liberated		Solution		Relative Volume Bbl/Bbl Residual Oil	Saturated Oil Density gm/cc	Compressibility Factor of Liberated Gas Z	Average Gravity of Liberated Gas (air=1)
	Gas-Oil Ratio SCF/Bbl	Residual Oil Residual Oil	Gas-Oil Ratio SCF/Bbl	Residual Oil Residual Oil				
2261			305.1		1.1619	0.8201		
2026	32.9		272.2		1.1481	0.8261	0.8858	0.622
1770	67.0		238.1		1.1360	0.8308	0.9049	0.620
1571	88.8		216.3		1.1263	0.8354	0.9103	0.620
1344	119.2		185.9		1.1156	0.8397	0.9174	0.623
1116	148.2		156.8		1.1049	0.8442	0.9258	0.628
917	174.9		130.2		1.0953	0.8482	0.9496	0.637
690	206.2		98.8		1.0839	0.8530	0.9596	0.652
488	233.4		71.7		1.0739	0.8573	0.9669	0.676
263	265.5		39.6		1.0617	0.8624	0.9748	0.718
0	305.1		0		1.0448	0.8691		0.881

at 60 °F = 1.0000

Residual oil specific gravity = 0.908 at 60 °F = 24.34 °API

Average gravity of total liberated gas 0.675

**Notes:**

- (1) Reservoir fluid bubble point pressure is 2261 psig at 160 °F
- (2) Gas/oil ratios are cubic feet of gas at 14.7 psia and 60°F per barrel of residual oil at 14.7 psia and 60°F.
- (3) Relative oil volumes are barrels of saturated reservoir oil per barrel of residual oil at 14.7 psia and 60°F.

SINTEF RESERVOIR FLUID STUDY

WELL : 31/2-3

COMPANY : Norske Shell A/S

Table 7. Experimental Liquid Phase Viscosity Data at 160 °F

<i>Pressure</i> <i>psig</i>	<i>Liquid Phase</i> <i>Viscosity, Cp.</i>
4593	2.314
3953	2.187
3143	2.026
2531	1.873
2304	1.847
2161	1.853
1891	1.920
1585	2.022
1173	2.263
818	2.528
412	2.967
0	3.977



SINTEF RESERVOIR FLUID STUDY

WELL : 31/2-3

COMPANY : Norske Shell A/S

Table 8. Separator Tests of "Separator Oil" Sample

	<u>Separator pressure, psig</u> -----
	0
Separator temperature, °F	60
Separator gas/oil ratio, CFB	217.3
Separator gas gravity, air=1	0.752
Stocktank oil gravity, °API	24.73
Bubble point formation	
Volume factor, Bbl/Bbl STO	1.105

Notes:

- (1) Gas and liquid volumes are expressed at standard conditions of 14.7 psia and 60°F.
- (2) Reservoir fluid bubble point pressure is 2261 psig at 160°F.
- (3) Gas/oil ratios are standard cubic feet of gas per barrel of stocktank oil.

SINTEF RESERVOIR FLUID STUDY

WELL : 31/2-3  
 COMPANY: Norske Shell A/S

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

<i>Component</i>	<i>Mole Fraction</i>		
	<i>Separator Gas</i>	<i>Separator Liquid</i>	<i>Reservoir Fluid</i>
Carbon dioxide	0.0070	0.0020	0.0026
Nitrogen	0.0210	0.0053	0.0071
Methane	0.9223	0.2456	0.3251
Ethane	0.0315	0.0337	0.0335
Propane	0.0033	0.0121	0.0111
iso-Butane	0.0036	0.0072	0.0068
n-Butane	0.0006	0.0024	0.0022
iso-Pentane	0.0007	0.0017	0.0016
n-Pentane	0.0003	0.0007	0.0007
Hexanes	0.0034	0.0066	0.0062
Heptanes plus	0.0063	0.6827	0.6031
	1.0000	1.0000	1.0000

Properties of Heptanes plus

Molecular weight 261.3  
 Specific gravity 0.9087 60/60 °F = 24.22° API

"Separator" Gas Properties

Gas gravity (air=1) 0.605  
 Pseudo-critical pressure, psia 672  
 Pseudo-critical temperature, °R 359

Separator Conditions

Stocktank operating at 0 psig and 60 °F  
 "Separator gas"/stocktank oil ratio = 90.7 SCF/STB  
 Stocktank vapor/stocktank oil ratio = 217.3 SCF/STB  
 "Separator oil"/stocktank oil ratio = 1.105 Bbl/Bbl

SINTEF RESERVOIR FLUID STUDY

WELL : 31/2-3  
 COMPANY: Norske Shell A/S

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

<i>Component</i>	<i>Mole Fraction</i>		
	<i>Separator Gas</i>	<i>Separator Liquid</i>	<i>Reservoir Fluid</i>
Carbon dioxide	0.0070	0.0020	0.0026
Nitrogen	0.0210	0.0053	0.0071
Methane	0.9223	0.2456	0.3251
Ethane	0.0315	0.0337	0.0335
Propane	0.0033	0.0121	0.0111
iso-Butane	0.0036	0.0072	0.0068
n-Butane	0.0006	0.0024	0.0022
iso-Pentane	0.0007	0.0017	0.0016
n-Pentane	0.0003	0.0007	0.0007
Hexanes	0.0034	0.0066	0.0062
Heptanes	0.0028	0.0287	0.0257
Octanes	0.0035	0.0415	0.0371
Nonanes		0.0251	0.0222
Decanes		0.0203	0.0179
Undecanes		0.0190	0.0168
Dodecanes		0.0177	0.0156
Tridecanes		0.0184	0.0162
Tetradecanes		0.0180	0.0159
Pentadecanes		0.0275	0.0242
Hexadecanes		0.0218	0.0192
Heptadecanes		0.0248	0.0219
Octadecanes		0.0201	0.0178
Nonadecanes		0.0166	0.0147
Eicosanes		0.0144	0.0127
Heneicosanes plus		0.3688	0.3252
	<u>1.0000</u>	<u>1.0000</u>	<u>1.0000</u>

Properties of Heneicosanes plus

Molecular weight 326.6  
 Specific gravity 0.996 60/60 °F = 10.57° API

SINTEF RESERVOIR FLUID STUDY

WELL : 31/2-3

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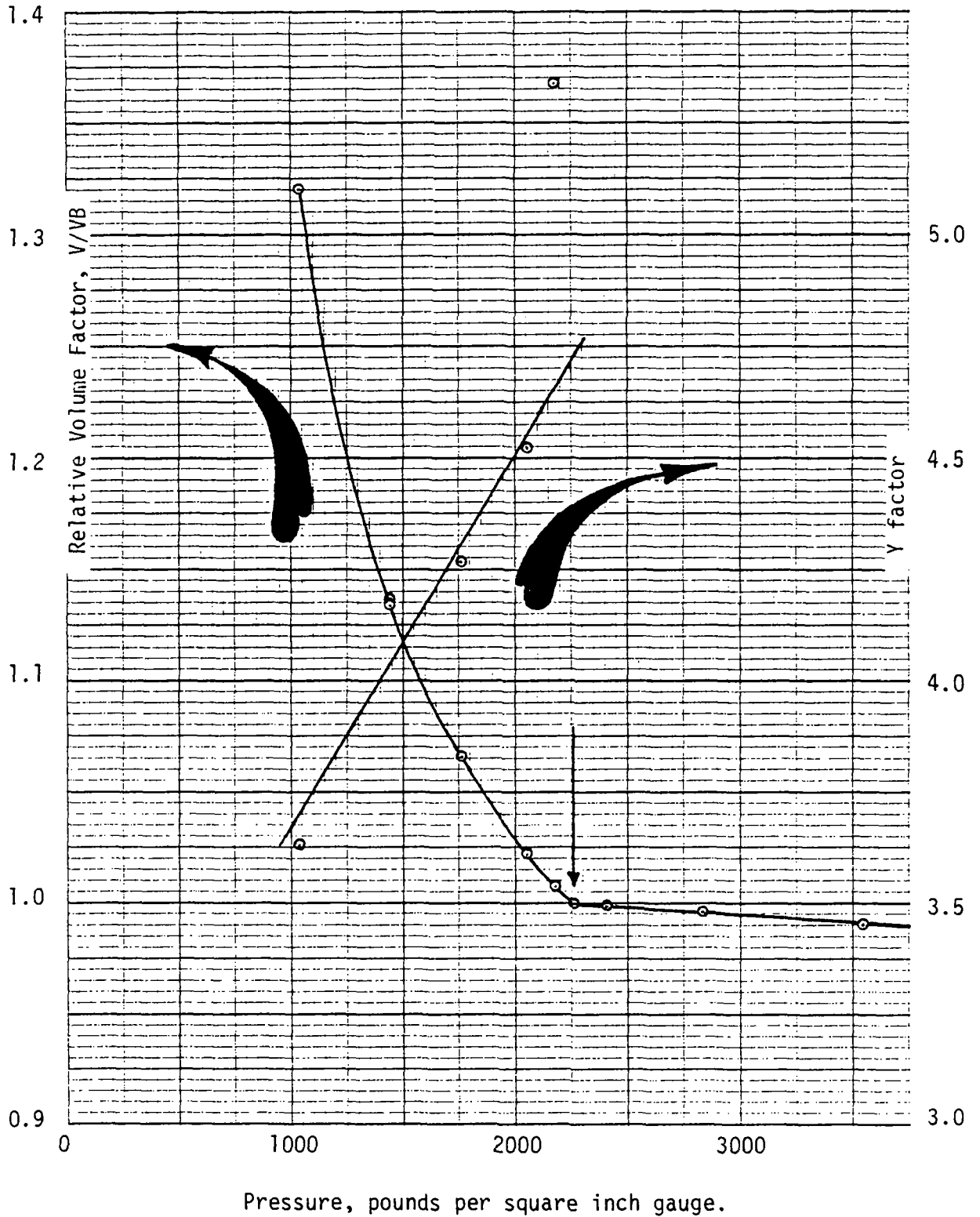


Figure 1. Experimental constant-composition pressure-volume and Y factor vs. pressure. Temperature 160 °F.

SINTEF RESERVOIR FLUID STUDY

WELL : 31/2-3

COMPANY : Norske Shell A/S

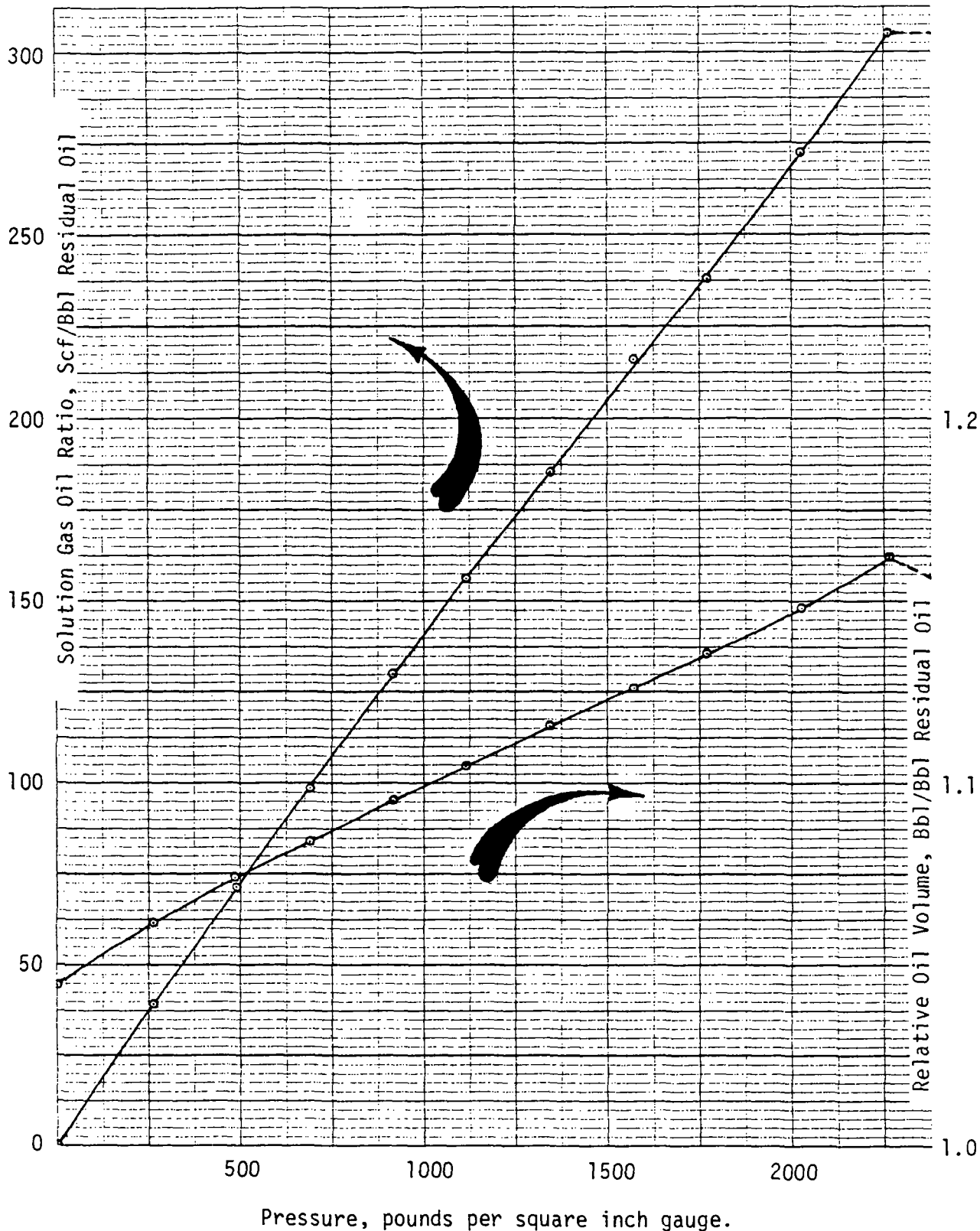


Figure 2. Experimental gas solubility and relative volume data vs. pressure. Differential gas liberation process. Temperature 160 °F.

SINTEF RESERVOIR FLUID STUDY

WELL : 31/2-3

COMPANY : Norske Shell A/S

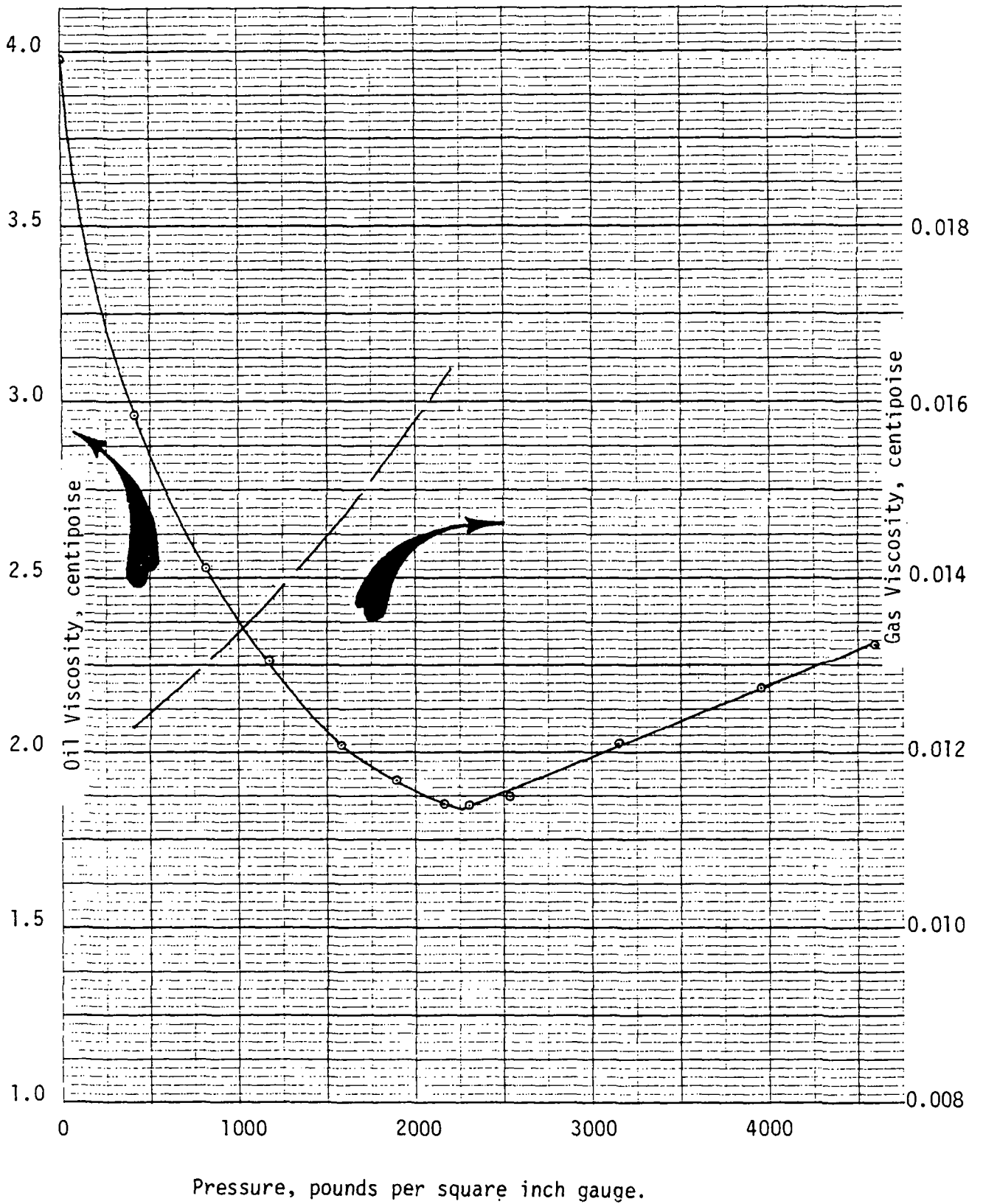


Figure 3. Experimental oil viscosity and calculated gas viscosity vs. pressure. Temperature 160 °F.

SINTEF RESERVOIR FLUID STUDY

WELL : 31/2-3  
 COMPANY : Norske Shell A/S

Table 1. Experimental Physical Properties Data.

<i>Fraction</i>	<i>Boiling point n-paraffins</i>	<i>Vol. - %</i>	<i>Σ Vol. - %</i>	<i>Spec. gravity 60/60°F</i>	<i>Molecular weight</i>
Dest. loss		2.88	2.9	0.619	
C <sub>7</sub>	98.4°C	0.45	3.3	0.738	90
C <sub>8</sub>	125.6°C	3.01	6.3	0.763	107
C <sub>9</sub>	150.8°C	2.85	9.2	0.788	118
C <sub>10</sub>	174.1°C	3.36	12.6	0.808	137
C <sub>11+</sub>	-	87.45	100.0	0.929	298

Molecular weight <sub>ST0</sub> = 260.2

Specific gravity <sub>ST0</sub> = 0.906