

RESERVOIR FLUID STUDY

For

A/S NORSKE SHELL

Well: 6407/9-1

Norwegian Sea

Norway

CORE LABORATORIES
Petroleum Reservoir Engineering
CCB, ÅGOTNES

19th December 1984

A/S Norske Shell
P.O. Box 10
N-4033 Forus
Norway

Attention: Mr. D. P. Krabbendam

Subject: Reservoir Fluid Study
Well: 6407/9-1
Norwegian Sea, Norway
Our File Number: RFLN 840049

Gentlemen,

On the 5th November 1984 three subsurface fluid samples, collected from the subject well, were received in our Aagotnes laboratory. Presented in the following report are the results of a reservoir fluid study performed on one of these samples, as requested by a representative of A/S Norske Shell.

Upon receipt in the laboratory, and as a quality check, the ambient temperature saturation pressures of the samples were determined to be 640 psig, 610 psig and 604 psig at 61°F for cylinder numbers 811514, 810822 and 811513 respectively.

Thereafter small portions of reservoir fluid from each cylinder were introduced to high pressure windowed cells and thermally expanded to the reported reservoir temperature of 155°F. During constant composition expansions at this temperature, the fluids were found to have bubble point pressures of 842 psig, 857 psig and 853 psig for cylinder numbers 811514, 810822 and 811513 respectively. The results of pressure-volume measurements recorded above the saturation pressure for cylinder numbers 811514 and 810822 respectively may be found on pages three and four.

As requested sample from cylinder number 811513 was utilized for the remainder of the study.

The hydrocarbon composition of the subsurface fluid was determined by low temperature fractional distillation. The results of this distillation in terms of both mol percent and weight percent are presented on page two.

The results of the pressure-volume measurements at reservoir temperature, recorded whilst determining the saturation pressure, may be found on page six.

When subjected to differential pressure depletion at the reservoir temperature, the fluid evolved a total of 395 cubic feet of gas at 14.7 psia and 60°F. per barrel of residual oil at 60°F. The resulting relative oil volume factor being 1.298 barrels of saturated fluid per barrel of residual oil. The oil density and the properties of the evolved gases were measured at each point during the differential pressure depletion and these data are included in the summary of the differential depletion data on page seven.

The viscosity of the reservoir fluid was measured over a wide range of pressures at 155°F. in a rolling ball viscosimeter. The viscosity of the fluid was found to vary from a minimum of 0.597 centipoise at the saturation pressure to a maximum of 1.618 centipoise at atmospheric pressure. The results of these viscosity measurements are tabulated on page eight.

Four single-stage separator tests were performed at laboratory temperature to determine the effects of separator pressure upon gas-oil, stock tank oil gravity and formation volume factor. The results of these separator tests are tabulated on page nine. The separator gas from each of the four tests was collected and analysed for hydrocarbon composition. The results of these separator gas analyses are given on page ten.

We appreciate this opportunity to have been of service to A/S Norske Shell. Should you have any questions or if we may be of further assistance in any way, please feel free to call upon us.

Very truly yours
Core Laboratories Norsk



Duncan Thow
Operation Supervisor
Reservoir Fluid Analysis

10 cc Addressee
DMT/ah

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Company <u>A/S Norske Shell</u>	Date Sampled <u>28th August 1984</u>
Well <u>6407/9-1</u>	County <u>Norwegian Sea</u>
Field <u>Haltenbanken</u>	State <u>Norway</u>

FORMATION CHARACTERISTICS

Formation Name	<u>Upper Jurassic</u>
Date First Well Completed	<u>, 1984</u>
Original Reservoir Pressure	<u>PSIG @ Ft.</u>
Original Produced Gas-Oil Ratio	<u>SCF/Bbl</u>
Production Rate	<u>Bbl/Day</u>
Separator Pressure and Temperature	<u>PSIG °F.</u>
Oil Gravity at 60°F.	<u>°API</u>
Datum	<u>Ft. Subsea</u>
Original Gas Cap	<u></u>

WELL CHARACTERISTICS

Elevation	<u>25 m</u>	<u>BDF.</u>
Total Depth	<u></u>	<u>Ft.</u>
Producing Interval	<u>1632 - 1638</u>	<u>m.</u>
Tubing Size and Depth	<u>3 1/2</u>	<u>In. to Ft.</u>
Productivity Index	<u>Bbl/D/PSI @</u>	<u>Bbl/Day</u>
Last Reservoir Pressure	<u>2348 PSIG @</u>	<u>1612 m.</u>
Date	<u></u>	<u>, 19</u>
Reservoir Temperature	<u>155°F. @</u>	<u>Ft.</u>
Status of Well	<u></u>	<u></u>
Pressure Gauge	<u></u>	<u></u>
Normal Production Rate	<u></u>	<u>Bbl/Day</u>
Gas-Oil Ratio	<u></u>	<u>SCF/Bbl</u>
Separator Pressure and Temperature	<u>PSIG,</u>	<u>°F.</u>
Base Pressure	<u></u>	<u>PSIA</u>
Well Making Water	<u></u>	<u>% Cut</u>

SAMPLING CONDITIONS

Sampled at	<u>1561.8</u>	<u>m.</u>
Status of Well	<u>Flowing through 8/64 choke</u>	
Gas-Oil Ratio	<u>227</u>	<u>SCF/Bbl</u>
Separator Pressure and Temperature	<u>27 PSIG,</u>	<u>101 °F.</u>
Tubing Pressure	<u>570</u>	<u>PSIG</u>
Casing Pressure	<u></u>	<u>PSIG</u>
Sampled by	<u>Flopetrol</u>	
Type Sampler	<u>Schumberger</u>	

REMARKS: Transferred to cylinder number 811513

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HYDROCARBON ANALYSIS OF RESERVOIR FLUID SAMPLE *

COMPONENT	MOL PERCENT	WEIGHT PERCENT	DENSITY	API	MOL WEIGHT
Carbon Dioxide	0.28	0.10			
Nitrogen	0.09	0.03			
Methane	16.13	2.06			
Ethane	4.81	1.16			
Propane	9.09	3.21			
iso-Butane	2.63	1.22			
n-Butane	7.02	3.27			
iso-Pentane	3.18	1.84			
n-Pentane	4.23	2.44			
Hexanes	4.15	2.85			
Heptanes	48.39	81.82	0.8526	34.3	212
	<u>100.00</u>	<u>100.00</u>			

* Cylinder Number 811513

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VOLUMETRIC DATA OF RESERVOIR FLUID SAMPLE *

1. Saturation pressure (bubble-point pressure) 842 PSIG at 155°F.
2. Thermal expansion of saturated oil at 5000 PSIG = $\frac{V \text{ at } 155^\circ\text{F.}}{V \text{ at } 60^\circ\text{F.}} = \underline{1.04714}$
3. Compressibility of saturated oil at reservoir temperature: Vol/Vol/PSI:

From	5000	PSI to	3500	PSI =	7.84×10^{-6}
From	3500	PSI to	2312	PSI =	8.63×10^{-6}
From	2312	PSI to	2000	PSI =	9.73×10^{-6}
From	2000	PSI to	1500	PSI =	10.07×10^{-6}
From	1500	PSI to	1200	PSI =	10.37×10^{-6}
From	1200	PSI to	1000	PSI =	10.79×10^{-6}
From	1000	PSI to	842	PSI =	10.76×10^{-6}

4. Pressure-Volume relations at 155°F.

<u>Pressure</u> PSIG	<u>Relative</u> <u>Volume</u> <u>V/Vsat(1)</u>
5000	0.9637
4000	0.9711
3500	0.9752
3000	0.9793
2500	0.9836
<u>2312</u> Reservoir Pressure	0.9852
2000	0.9882
1700	0.9912
1500	0.9932
1300	0.9953
1200	0.9963
1100	0.9974
1000	0.9984
900	0.9994
<u>842</u> Saturation Pressure	1.0000

* Cylinder number 811514

Disse analysene, eller tokningene baseres på observasjoner og materiell skaffet til veie av klienter, som denne rapporten eksklusivt og fortrolig er laget for. Det utførte arbeidet representerer de beste tolkninger Core Laboratories Norsk er i stand til å gi, (med forbehold om feil og utelatelser). Likevel frasier Core Laboratories Norsk og Deres personell seg alt ansvar og gir derfor ingen overslag på grunnlag av disse data, som f.eks produktivitet, aktuelle operasjoner, og lønnsomhet fra en hver olje, gass eller mineral brønn eller sand, som en slik rapport er basert på.

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VOLUMETRIC DATA OF RESERVOIR FLUID SAMPLE *

1. Saturation pressure (bubble-point pressure) 857 PSIG at 155°F.
2. Thermal expansion of saturated oil at 5000 PSIG = $\frac{V \text{ at } 155^\circ\text{F.}}{V \text{ at } 61^\circ\text{F.}} = \underline{1.04934}$
3. Compressibility of saturated oil at reservoir temperature: Vol/Vol/PSI:

From	<u>5000</u>	PSI to	<u>3500</u>	PSI =	<u>7.69×10^{-6}</u>
From	<u>3500</u>	PSI to	<u>2312</u>	PSI =	<u>8.80×10^{-6}</u>
From	<u>2312</u>	PSI to	<u>2000</u>	PSI =	<u>9.73×10^{-6}</u>
From	<u>2000</u>	PSI to	<u>1500</u>	PSI =	<u>10.27×10^{-6}</u>
From	<u>1500</u>	PSI to	<u>1200</u>	PSI =	<u>10.40×10^{-6}</u>
From	<u>1200</u>	PSI to	<u>1000</u>	PSI =	<u>11.38×10^{-6}</u>
From	<u>1000</u>	PSI to	<u>857</u>	PSI =	<u>11.26×10^{-6}</u>

4. Pressure-Volume relations at 155°F.

<u>Pressure</u> PSIG	<u>Relative</u> <u>Volume</u> <u>V/Vsat(1)</u>
5000	0.9634
4000	0.9706
3500	0.9746
3000	0.9786
2500	0.9830
2312 Reservoir	0.9849
2000 Pressure	0.9879
1800	0.9899
1500	0.9931
1400	0.9940
1300	0.9950
1200	0.9961
1100	0.9972
1000	0.9984
900	0.9997
<u>857</u> Saturation Pressure	1.0000

* Cylinder number 810822

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VOLUMETRIC DATA OF RESERVOIR FLUID SAMPLE *

1. Saturation pressure (bubble-point pressure) 853 PSIG at 155°F.
2. Specific volume at saturation pressure: ft³/lb 0.02175 at 155°F.
3. Thermal expansion of saturated oil at 5000 PSIG = $\frac{V \text{ at } 155^\circ\text{F.}}{V \text{ at } 60^\circ\text{F.}} = \underline{1.04749}$
4. Compressibility of saturated oil at reservoir temperature: Vol/Vol/PSI:

From	5000	PSI	to	3500	PSI	=	7.58×10^{-6}
From	3500	PSI	to	2312	PSI	=	8.57×10^{-6}
From	2312	PSI	to	2000	PSI	=	8.91×10^{-6}
From	2000	PSI	to	1500	PSI	=	9.64×10^{-6}
From	1500	PSI	to	1200	PSI	=	10.21×10^{-6}
From	1200	PSI	to	1000	PSI	=	10.40×10^{-6}
From	1000	PSI	to	853	PSI	=	10.89×10^{-6}

* Cylinder number 811513

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PRESSURE-VOLUME RELATIONS AT 155°F.

<u>Pressure</u> <u>PSIG</u>	<u>Relative</u> <u>Volume</u> <u>V/Vsat(1)</u>	<u>Y</u> <u>Function(2)</u>
5000	0.9646	
4500	0.9682	
4000	0.9718	
3500	0.9757	
3000	0.9797	
2500	0.9839	
2312 Reservoir	0.9857	
2000 Pressure	0.9885	
1500	0.9933	
1300	0.9953	
1200	0.9963	
1100	0.9973	
1000	0.9984	
900	0.9995	
853 Saturation	1.0000	
Pressure		
851	1.0014	2.008
849	1.0025	2.007
847	1.0035	2.005
817	1.0219	1.983
786	1.0426	1.964
733	1.0837	1.916
648	1.1662	1.860
569	1.2701	1.796
500	1.3952	1.734
434	1.5589	1.670
365	1.8086	1.588
293	2.2218	1.488
229	2.8429	1.388
171	3.8848	1.269

(1) Relative Volume: V/Vsat is barrels at indicated pressure per barrel at saturation pressure.

(2) Y Function =
$$\frac{(P_{sat}-P)}{(P_{abs}) (V/V_{sat}-1)}$$

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DIFFERENTIAL VAPORISATION AT 155°F.

<u>Pressure PSIG</u>	<u>Solution Gas/Oil Ratio(1)</u>	<u>Relative Oil Volume(2)</u>	<u>Relative Total Volume(3)</u>	<u>Oil Density gm/cc</u>	<u>Deviation Factor Z</u>	<u>Gas Formation Volume Factor(4)</u>	<u>Incremental Gas Gravity</u>
853	395	1.298	1.298	0.7363			
700	354	1.279	1.444	0.7421	0.924	0.02246	0.772
600	326	1.266	1.587	0.7455	0.929	0.02625	0.781
500	299	1.254	1.795	0.7493	0.936	0.03162	0.795
400	271	1.239	2.112	0.7539	0.943	0.03953	0.822
300	240	1.224	2.677	0.7588	0.953	0.05265	0.869
200	206	1.205	3.835	0.7645	0.965	0.07814	0.951
112	167	1.182	6.626	0.7710	0.977	0.13406	1.173
0	0	1.044		0.8065			1.905

At 60°F = 1.000

Gravity of residual oil = 36.4°API @ 60°F.

- (1) Cubic feet of gas at 14.7 psia and 60°F. per barrel of residual oil at 60°F.
- (2) Barrels of oil at indicated pressure and temperature per barrel of residual oil at 60°F.
- (3) Barrels of oil plus liberated gas at indicated pressure and temperature per barrel of residual oil at 60°F.
- (4) Cubic feet of gas at indicated pressure and temperature per cubic foot at 14.7 psia and 60°F.

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VISCOSITY DATA AT 155°F.

<u>Pressure</u> <u>PSIG</u>	<u>Oil Viscosity</u> <u>Centipoise</u>	<u>Calculated</u> <u>Gas Viscosity</u> <u>Centipoise +</u>	<u>Oil/Gas</u> <u>Viscosity</u> <u>Ratio</u>
5000	0.833		
4500	0.805		
4000	0.776		
3500	0.747		
3000	0.719		
2500	0.691		
<u>2312</u> Reservoir Pressure	0.681		
2000	0.663		
1500	0.634		
1000	0.606		
<u>853</u> Saturation Pressure	0.597		
700	0.618	0.0122	50.5
600	0.639	0.0120	53.3
500	0.662	0.0118	55.9
400	0.686	0.0117	58.9
300	0.725	0.0114	63.5
200	0.777	0.0111	70.2
112	0.823	0.0104	79.1
0	1.618		

+ Calculated using the correlation of Carr, Kobayashi and Burrows, AIME transactions, 1954, Vol 201, p 264

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SEPARATOR TESTS OF RESERVOIR FLUID SAMPLE

Separator Pressure PSI Gauge	Separator Temperature °F.	Gas/Oil Ratio (1)	Gas/Oil Ratio (2)	Stock Tank Gravity °API @ 60°F.	Formation Volume Factor (3)	Separator Volume Factor (4)	Specific Gravity of Flashed Gas
250	60	102	116			1.120	0.690 *
TO							
0	60	190	193	39.6	1.211	1.000	1.275
150	60	143	156			1.091	0.736 *
TO							
0	60	135	135	40.1	1.202	1.000	1.326
100	60	171	183			1.068	0.785 *
TO							
0	60	99	99	40.4	1.197	1.000	1.366
50	60	212	220			1.039	0.887 *
TO							
0	60	52	52	40.7	1.193	1.000	1.409 *

* Gases collected and analysed for hydrocarbon composition

- (1) Gas/Oil Ratio in cubic feet of gas at 14.7 psia and 60°F. per barrel of oil at indicated pressure and temperature.
- (2) Gas/Oil Ratio in cubic feet of gas at 14.7 psia and 60°F. per barrel of stock tank oil at 60°F.
- (3) Formation Volume Factor is barrels of saturated oil at 853 psig and 155°F. per barrel of stock tank oil at 60°F.
- (4) Separator Volume Factor is barrels of oil at indicated pressure and temperature per barrel of stock tank oil at 60°F.

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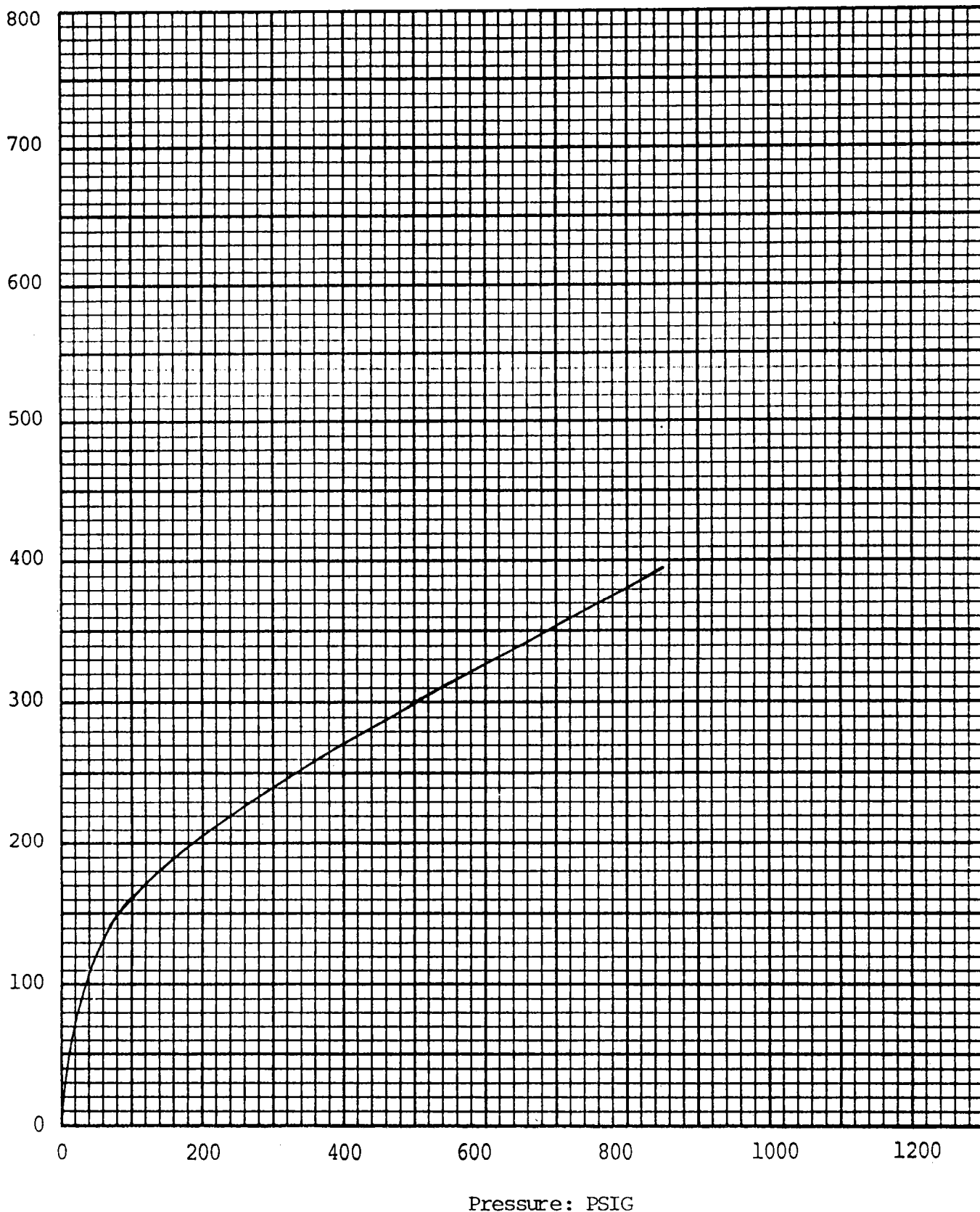
HYDROCARBON ANALYSES OF SEPARATOR GAS SAMPLES

<u>Separator Conditions:</u>	<u>50 PSIG at 60°F.</u>		<u>100 PSIG at 61°F.</u>		<u>150 PSIG at 61°F.</u>		<u>250 PSIG at 61°F.</u>	
<u>Component</u>	<u>Mol Percent</u>	<u>GPM</u>	<u>Mol Percent</u>	<u>GPM</u>	<u>Mol Percent</u>	<u>GPM</u>	<u>Mol Percent</u>	<u>GPM</u>
Carbon Dioxide	0.97		0.99		0.98		0.90	
Nitrogen	0.27		0.33		0.38		0.47	
Methane	63.65		73.31		78.34		83.43	
Ethane	13.43	3.581	11.52	3.072	9.87	2.632	7.74	2.064
Propane	14.17	3.890	9.12	2.503	6.97	1.913	5.06	1.389
iso-Butane	2.07	0.675	1.28	0.418	0.92	0.300	0.63	0.206
n-Butane	3.70	1.163	2.36	0.742	1.73	0.544	1.18	0.371
iso-Pentane	0.66	0.241	0.42	0.153	0.31	0.113	0.22	0.080
n-Pentane	0.63	0.228	0.39	0.141	0.29	0.105	0.21	0.076
Hexanes	0.28	0.114	0.17	0.069	0.13	0.053	0.10	0.041
Heptanes plus	0.17	0.077	0.11	0.050	0.08	0.036	0.06	0.027
	<u>100.00</u>	<u>9.969</u>	<u>100.00</u>	<u>7.148</u>	<u>100.00</u>	<u>5.696</u>	<u>100.00</u>	<u>4.254</u>
Calculated gas gravity (air = 1.000):		<u>0.887</u>		<u>0.785</u>		<u>0.736</u>		<u>0.690</u>
Calculated gross heating value (BTU per cubic foot of dry gas at 14.7 psia and 60°F):		<u>1500</u>		<u>1339</u>		<u>1262</u>		<u>1191</u>

Differential Vapourization Of Reservoir Fluid At 155°F

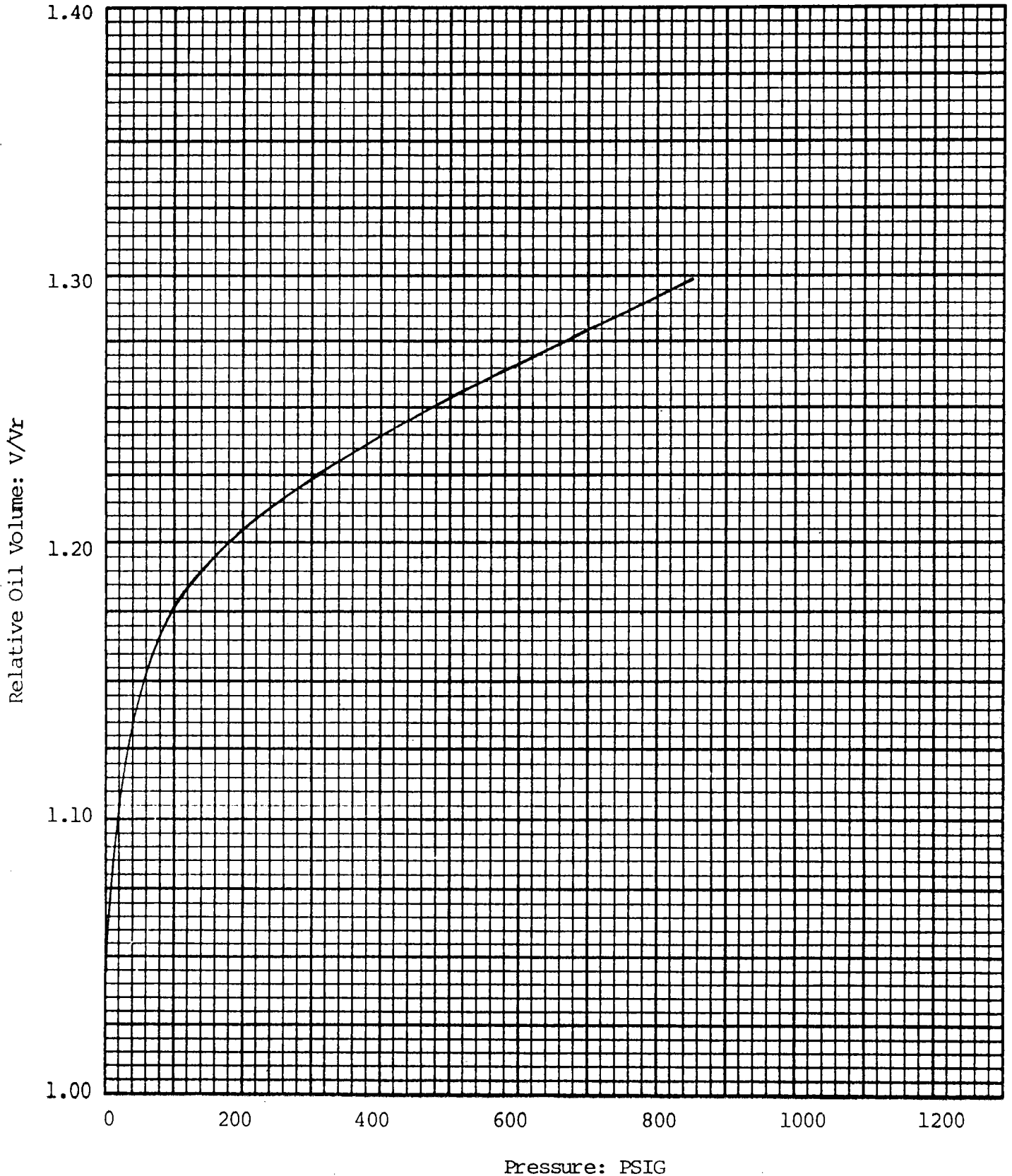
Company	<u>A/S Norske Shell</u>	Formation	<u>Upper Jurassic</u>
Well	<u>6407/9-1</u>	Province	<u>Norwegian Sea</u>
Field	<u>Haltenbanken</u>	Country	<u>Norway</u>

Solution Gas - Oil Ratio: S.C.F. Per Residual Barrel At 60°F.

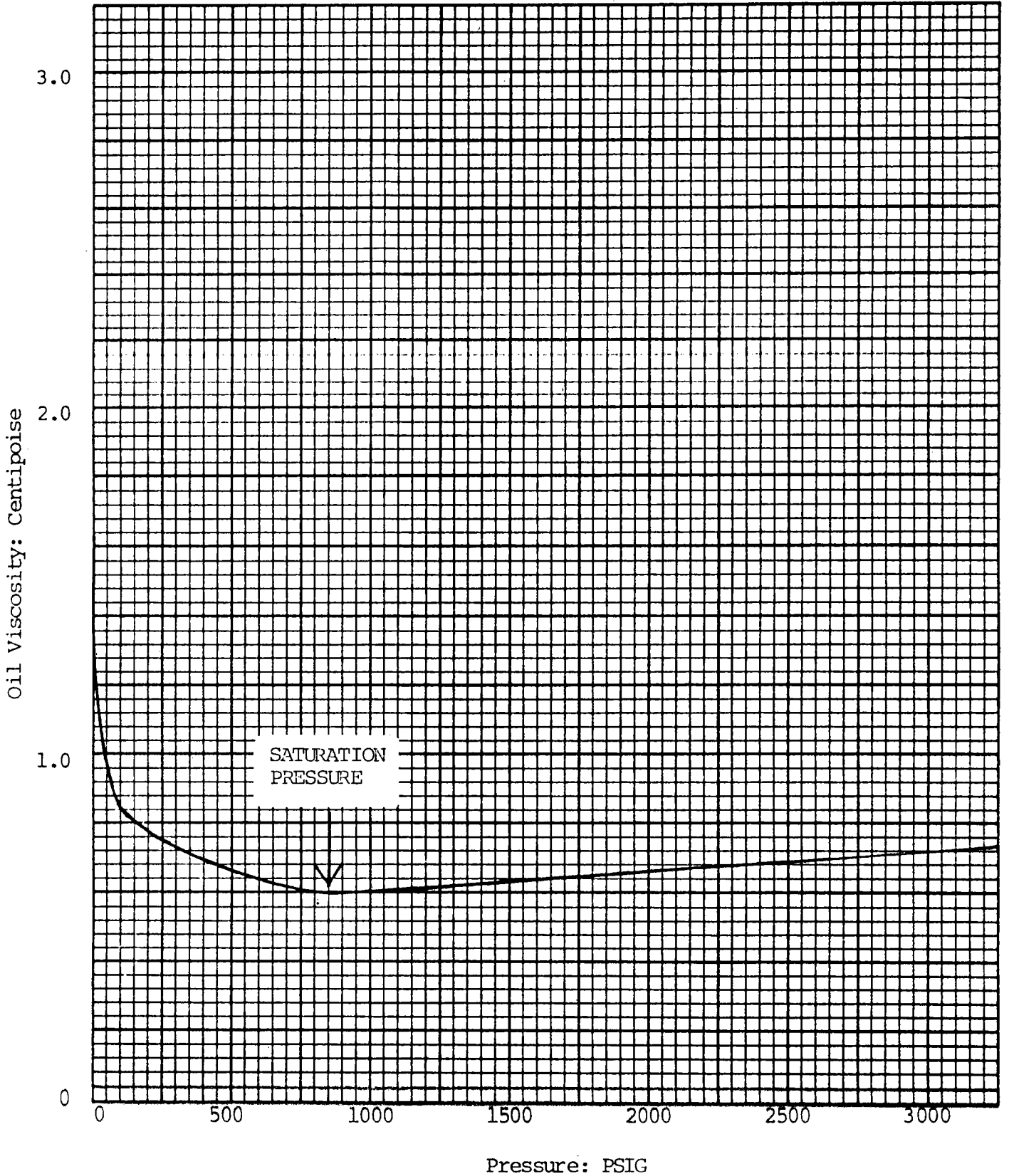


Differential Vapourization Of Reservoir Fluid At 155°F.

Company	<u>A/S Norske Shell</u>	Formation	<u>Upper Jurassic</u>
Well	<u>6407/9-1</u>	Province	<u>Norwegian Sea</u>
Field	<u>Haltenbanken</u>	Country	<u>Norway</u>



Company	<u>N/S Norske Shell</u>	Formation	<u>Upper Jurassic</u>
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A/S Norske Shell
Well: 6407/9-1

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Core Laboratories Norsk
Reservoir Fluid Laboratory



Duncan Thow
Operations Supervisor