

Denne rapport
tilhører



L&U DOK. SENTER

L. NR. 20088370022

KODE Well 31/2-9 nr. 2

Returneres etter bruk

RESERVOIR FLUID STUDY

for

A/S Norske Shell Exploration & Production

Well: 31/2-9

North Sea, Norway.

CORE LABORATORIES UK LTD.
Petroleum Reservoir Engineering
ABERDEEN, SCOTLAND

RESERVOIR FLUID STUDY

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CORE LABORATORIES UK LTD.

Petroleum Reservoir Engineering

ABERDEEN, SCOTLAND

1st February 1983

A/S Norske Shell Exploration & Production
Gamle Forusvei 43
P.O. Box 10
N-4033
Forus
NORWAY

Subject: Reservoir Fluid Study
Well: 31/2-9
Field: Troll
North Sea, Norway.
Our File: RFLA 820292

Attention: Mr. J. C. Jolly.

Gentlemen,

On the 6th June 1982, samples of separator gas and liquid were collected from the subject well. These samples were submitted to our Aberdeen laboratory for use in a reservoir fluid study, the results of which are presented in the following report.

On arrival in the laboratory the hydrocarbon compositions of the gas samples were determined by gas chromatography, and the gas in cylinder number A4796 was found to be contaminated. The composition of the gas from cylinder number A3908 is presented on page two of this report. Stock tank liquid from the RFT provided and gas were recombined to produce a saturation pressure of 2280 psig at 154°F as requested, and the resulting fluid was used for the entire study.

The hydrocarbon composition of the fluid to heptanes plus was determined by low temperature fractional distillation. This composition in terms of both mol and weight percent may be found on page three of this report. The hydrocarbon composition to eicosanes plus will be reported shortly in a supplementary report.

A portion of the reservoir fluid was placed in a high pressure visual cell and thermally expanded to the reservoir temperature of 154°F. During a constant composition expansion at this temperature, a saturation pressure of 2280 psig was observed. The results of the pressure-volume relations may be found on page five, with the associated volumetric data for the undersaturated fluid presented on page four.

A large volume of reservoir fluid was then subjected to a differential vaporisation at 154°F, resulting in the liberation of a total of 291 standard cubic feet of gas per barrel of residual oil, with an associated relative volume of 1.146 barrels of saturated fluid per barrel of residual oil. At several pressure levels below the observed saturation pressure, oil density, gas gravity and gas compressibility factor were monitored. These data are tabulated on page six, and graphically represented on pages eleven and twelve.

The viscosity of the liquid phase was measured in a rolling ball viscosimeter at the reservoir temperature of 154°F. These measurements were made over a wide range of pressures, from above saturation pressure to atmospheric pressure, and showed a minimum viscosity of 1.704 centipoise at saturation pressure, and a maximum of 3.666 centipoise at atmospheric pressure. This data, together with the calculated gas viscosity is presented on page seven, and graphically represented on page thirteen.

Continued Over/.....

At conditions specified by A/S Norske Shell Exploration & Production, a series of flash separation tests were performed in the laboratory. The factors and data derived from these tests may be found on page eight.

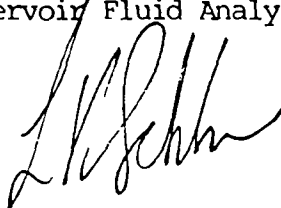
On the first separator test at both primary and secondary stages, the gas evolved was collected and analysed for hydrocarbon composition to undecanes plus by gas chromatography. These compositions are presented on page nine of this report.

It was requested that we analyse the residual liquid from the 450 psig flash separation test to determine pour point, cloud point, wax content and melting point of the wax. These results may be found on page ten.

It has been a pleasure to be of service to A/S Norske Shell Exploration & Production. Should any questions arise concerning data presented in this report, or if we may be of assistance in any matter, please do not hesitate to contact us.

Very truly yours

Core Laboratories UK Limited
Reservoir Fluid Analysis



Les. K. Sebborn
Manager - RFL Aberdeen

LKS/TGB/stb
10cc/Addressee

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Company A/S Norske Shell Expl. & Prod. Date Sampled 6th June 1982

Well 31/2-9 County North Sea

Field Troll State Norway

FORMATION CHARACTERISTICS

Formation Name	_____
Date First Well Completed	_____, 19____
Original Reservoir Pressure	_____ PSIG @ _____ M.
Original Produced Gas-Liquid Ratio	_____ SCF/Bbl
Production Rate	_____ Bbls/Day
Separator Pressure and Temperature	_____ PSIG _____ °F.
Liquid Gravity at 60°F.	_____ °API
Datum	_____ M. Subsea

WELL CHARACTERISTICS

Elevation	_____ R.K.B.
Total Depth	_____ M.
Producing Interval	_____ M.
Tubing Size and Depth	_____ M.
Open Flow Potential	_____ MMSCF/Day
Last Reservoir Pressure	_____ PSIG @ _____ M.
Date	_____ , 1982
Reservoir Temperature	_____ °F. @ _____ M.
Status of Well	_____
Pressure Gauge	_____

SAMPLING CONDITIONS

Wellhead Tubing Pressure	_____ 223 _____ PSIG
Flowing Bottom Hole Pressure	_____ PSIG
Primary Separator Pressure	_____ 92 _____ PSIG
Primary Separator Temperature	_____ 71 _____ °F.
Secondary Separator Pressure	_____ PSIG
Secondary Separator Temperature	_____ °F.
Field Stock Tank Liquid Gravity	_____ °API @ 60°F.
Primary Separator Gas Production Rate	_____ MMSCF/Day
Pressure Base	_____ 14.73 _____ PSIA
Temperature Base	_____ 60 _____ °F.
Compressibility Factor (F_{pv})	_____ 1.009 _____
Gas Gravity (Laboratory)	_____ 0.640 _____
Gas Gravity Factor (F_G)	_____ 1.250 _____
Primary Sep Liquid Production Rate @ 71°F.	_____ Bbls/Day
Primary Separator Gas/ Separator Liquid Ratio	_____ SCF/Bbl
	_____ or _____ Bbls/MMSCF
Sampled by	_____ Flopetrol _____

REMARKS: *Milled Out Section.

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Company A/S Norske Shell Expl. & Prod. Formation

Well 31/2-9 County North Sea

Field Troll State Norway

HYDROCARBON ANALYSIS OF SEPARATOR GAS SAMPLE*

COMPONENT	MOL PERCENT	GPM
Hydrogen Sulfide	NIL	
Carbon Dioxide	1.22	
Nitrogen	0.80	
Methane	88.06	
Ethane	7.40	
Propane	1.23	0.338
iso-Butane	0.72	0.236
n-Butane	0.13	0.041
iso-Pentane	0.12	0.044
n-Pentane	0.02	0.007
Hexanes	0.15	0.061
Heptanes plus	0.15	0.068
	<u>100.00</u>	<u>0.795</u>

Calculated gas gravity (air = 1.000) = 0.640

Calculated gross heating value = 1103 BTU per cubic foot of dry gas at 14.73 psia and 60°F.

Collected at 92 psig and 71°F.

* Cylinder Number: A3908.

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Company A/S Norske Shell Expl. & Prod. Formation _____

Well 31/2-9 County North Sea

Field Troll State Norway

HYDROCARBON ANALYSIS OF RESERVOIR FLUID SAMPLE

COMPONENT	MOL PERCENT	WEIGHT PERCENT	DENSITY	API	MOL WEIGHT
Hydrogen Sulfide	NIL	NIL			
Carbon Dioxide	0.48	0.13			
Nitrogen	0.79	0.14			
Methane	30.21	3.04			
Ethane	3.51	0.66			
Propane	0.79	0.22			
iso-Butane	0.91	0.33			
n-Butane	0.22	0.08			
iso-Pentane	0.38	0.17			
n-Pentane	0.11	0.05			
Hexanes	0.43	0.23			
Heptanes plus	62.17	94.95	0.8833	28.5	244
	<u>100.00</u>	<u>100.00</u>			

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Well 31/2-9

VOLUMETRIC DATA OF RESERVOIR FLUID SAMPLE

1. Saturation pressure (bubble-point pressure) 2280 PSIG @ 154 °F.
2. Specific volume at saturation pressure: ft³/lb 0.01979 @ 154 °F.
 $\frac{V @ 154 \text{ } ^\circ\text{F.}}{V @ 60 \text{ } ^\circ\text{F.}} = 1.03744$
3. Thermal expansion of saturated oil @ 5000 PSIG = $\frac{V @ 154 \text{ } ^\circ\text{F.}}{V @ 60 \text{ } ^\circ\text{F.}} = 1.03744$
4. Compressibility of saturated oil @ reservoir temperature: Vol/Vol/PSI:
From 5000 PSIG to 4000 PSIG = 5.66 x 10⁻⁶
From 4000 PSIG to 3000 PSIG = 6.23 x 10⁻⁶
From 3000 PSIG to 2280 PSIG = 6.81 x 10⁻⁶

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Well 13/2-9

PRESSURE-VOLUME RELATIONS AT 154°F.

Pressure PSIG	Relative Volume(1)	Y Function(2)
5000	0.9833	
4000	0.9889	
3000	0.9951	
2700	0.9971	
2600	0.9978	
2500	0.9985	
2400	0.9992	
2300	0.9999	
<u>2280</u> Saturation Pressure	1.0000	
2256	1.0020	5.322
2239	1.0034	5.303
2222	1.0049	5.295
2206	1.0063	5.280
2160	1.0106	5.228
2061	1.0206	5.132
1985	1.0292	5.059
1829	1.0499	4.903
1651	1.0799	4.726
1463	1.1217	4.541
1263	1.1832	4.343
1118	1.2442	4.200
970	1.3278	4.057
860	1.4115	3.944
735	1.5387	3.824
620	1.7062	3.702
520	1.9125	3.605
395	2.3211	3.480
285	2.9692	3.377
185	4.1936	3.280

- (1) Relative Volume: V/V_{sat} 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 154°F.

Pressure PSIG	Solution Gas/Oil Ratio(1)	Relative Oil Volume(2)	Relative Total Volume(3)	Oil Density gm/cc	Deviation Factor Z	Gas Formation Volume Factor(4)	Incremental Gas Gravity
2280	291	1.146	1.146	0.8097			
2150	276	1.141	1.159	0.8112	0.836	0.00672	0.767
1800	237	1.128	1.206	0.8159	0.848	0.00813	0.717
1500	203	1.116	1.271	0.8200	0.862	0.00990	0.676
1200	168	1.104	1.380	0.8241	0.881	0.01261	0.644
900	133	1.091	1.575	0.8287	0.904	0.01718	0.627
600	94	1.078	2.003	0.8338	0.932	0.02636	0.630
300	52	1.063	3.329	0.8396	0.964	0.05323	0.653
200	36	1.058	4.640	0.8418	0.975	0.07887	0.671
100	20	1.052	8.257	0.8443	0.987	0.14928	0.699
0	0	1.041		0.8489			0.940
		At 60°F = 1.000					

Gravity of Residual Oil = 28.5° API at 60°F.

- (1) Cubic feet of gas at 14.73 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 14.73 psia and 60°F.

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 Well 31/2-9

VISCOSITY DATA AT 154°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	2.182		
4000	2.008		
3500	1.920		
3000	1.831		
2500	1.745		
<u>2280</u> Saturation Pressure	1.704		
2150	1.713	0.0178	96.4
1800	1.804	0.0161	111.8
1500	1.944	0.0151	128.6
1200	2.143	0.0144	149.2
900	2.407	0.0138	174.4
600	2.747	0.0132	207.8
300	3.183	0.0127	250.7
200	3.343	0.0125	267.7
100	3.507	0.0122	286.3
0	3.666		

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Well 31/2-9

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
450	58	190	197			1.037	0.598*
to 0	58	89	89	28.8	1.142	0.999	0.719*
250	58	230	235			1.021	0.620
to 0	58	51	51	28.8	1.142	0.999	0.749
150	58	253	256			1.012	0.634
to 0	58	31	31	28.8	1.142	0.999	0.764
50	58	276	277			1.004	0.661
to 0	58	11	11	28.8	1.142	0.999	0.756

* Gas collected and analysed for extended hydrocarbon composition.

- (1) Gas/Oil Ratio in cubic feet of gas at 14.73 psia and 60°F. per barrel of oil at indicated pressure and temperature.
- (2) Gas/Oil Ratio in cubic feet of gas at 14.73 psia and 60°F. per barrel of stock tank oil at 60°F.
- (3) Formation Volume Factor is barrels of saturated oil at 2280 psig and 154°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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Well 31/2-9

HYDROCARBON ANALYSES OF SEPARATOR GAS SAMPLES

<u>Separator Conditions:</u>	<u>450 PSIG @ 58°F.</u>		<u>0 PSIG @ 58°F.</u>	
<u>Component</u>	<u>Mol Percent</u>	<u>GPM</u>	<u>Mol Percent</u>	<u>GPM</u>
Hydrogen Sulfide	NIL		NIL	
Carbon Dioxide	0.81		1.89	
Nitrogen	3.30		0.68	
Methane	92.29		77.83	
Ethane	3.04		14.20	
Propane	0.27	0.074	2.43	0.669
iso-Butane	0.13	0.043	1.65	0.540
n-Butane	0.04	0.013	0.34	0.107
iso-Pentane	0.03	0.011	0.34	0.125
n-Pentane	0.01	0.004	0.17	0.062
Hexanes	0.03	0.012	0.14	0.057
Heptanes	0.03)	0.23)
Octanes	0.01) 0.023	0.07) 0.150
Nonanes plus	0.01)	0.03)
	<u>100.00</u>	<u>0.180</u>	<u>100.00</u>	<u>1.710</u>

Calculated gas gravity(Air=1.000): 0.598 0.719

Calculated gross heating value
(BTU per cubic foot of dry gas
at 14.73 psia and 60°F.): 1007 1212

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Well 31/2-9

ANALYSIS OF RESIDUAL LIQUID FROM FLASH SEPARATION TEST*

Pour Point	L -50°C
Cloud Point	-20°C
Wax Content	2.77
Drop melting point of wax (IP 133)	50.8°C

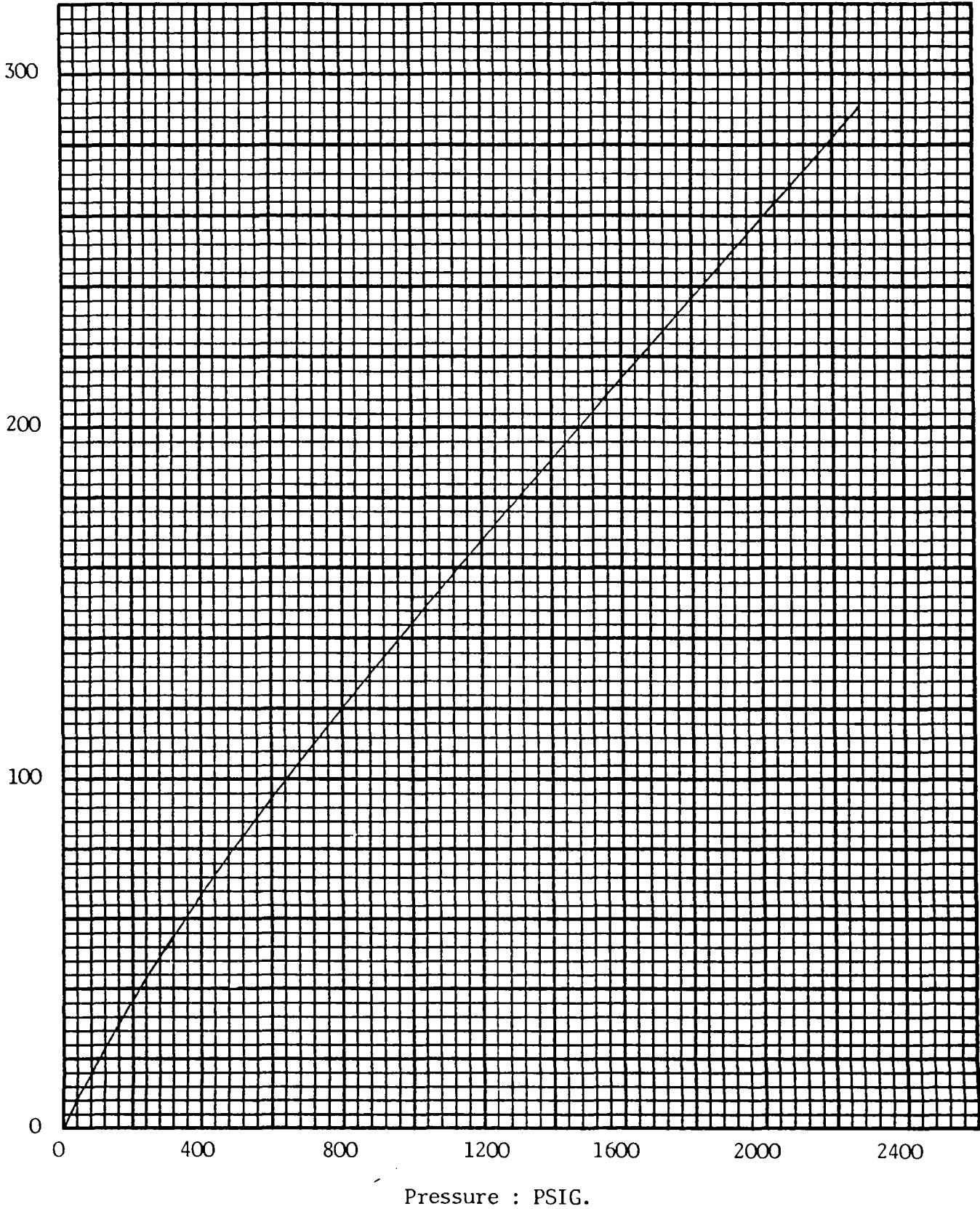
L = Less Than

* 450 psig @ 58°F to 0 psig @ 58°F.

Differential Vaporisation of Reservoir Fluid at 154° F.

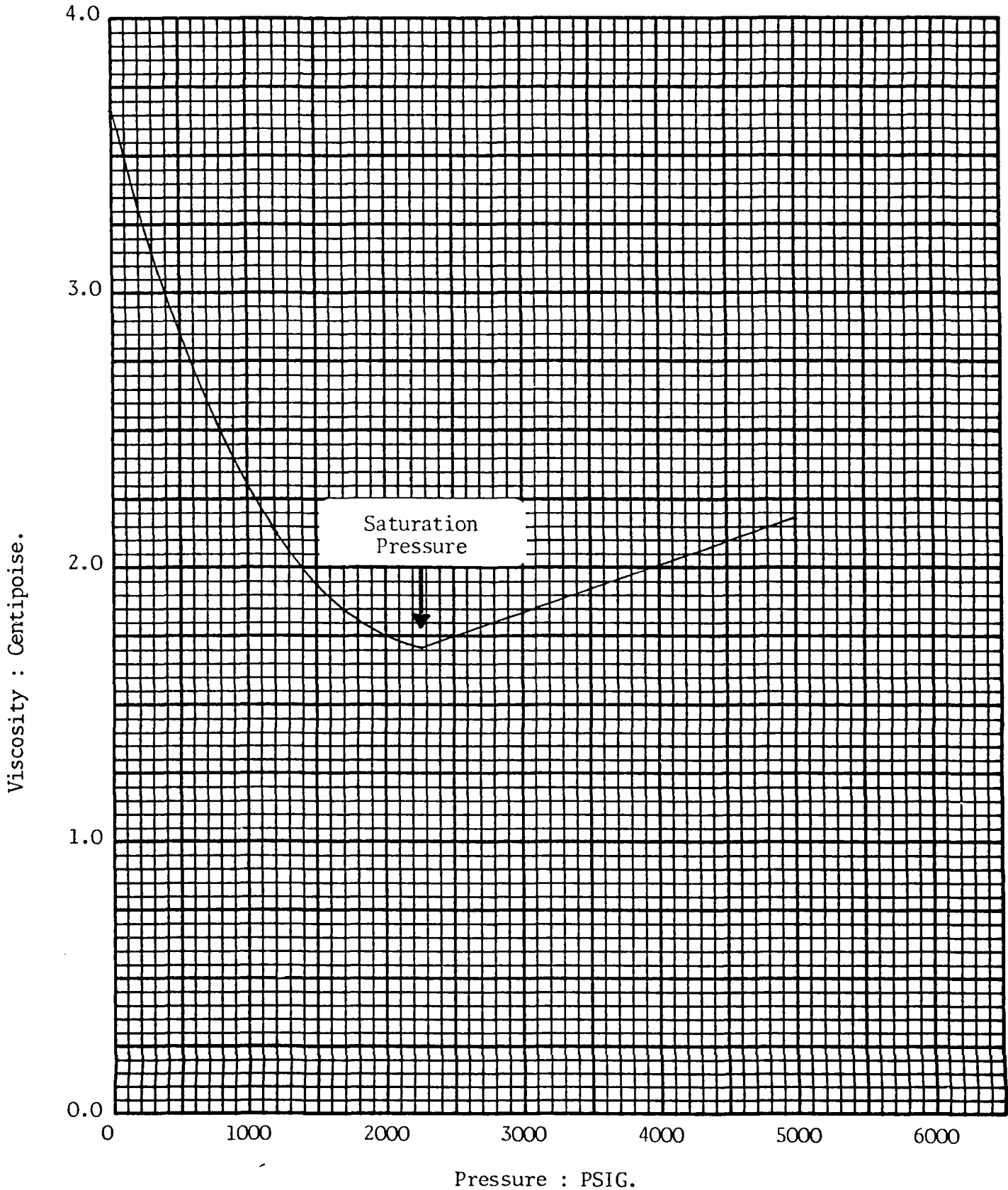
Company A/S Norske Shell Expl. & Prod. Formation _____
Well 31/2-9 County North Sea
Field Troll State United Kingdom

Solution Gas-Oil Ratio : Standard Cubic Feet of Gas per Barrel of Residual Oil.



Viscosity of Reservoir Fluid at 154° F.

Company A/S Norske Shell Expl. & Prod. Formation _____
Well 31/2-9 County North Sea
Field Troll State Norway

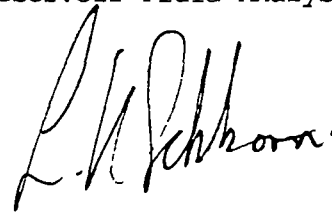


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ABERDEEN, SCOTLAND

A/S NORSKE SHELL EXPLORATION & PRODUCTION
Well: 31/2-9

RFLA 820292

Core Laboratories UK Limited
Reservoir Fluid Analysis

A handwritten signature in black ink, appearing to read 'L. K. Sebborn', written in a cursive style.

Les. K. Sebborn
Manager - RFL Aberdeen

31/2-9 RFT SAMPLES

The first two paragraphs of Corelab's covering letter to this report require clarification. The following account explains the procedures employed in the recovery and analysis of RFT samples from well 31/2-9.

An unsegregated and a segregated RFT sample were taken in the 31/2-9 oil zone. The unsegregated sample was drained into steel cans on the rig and the RFT chamber containing the segregated sample was sent to shore for transfer. During the transfer it became evident that the chamber contained only a small amount of oil (later found to be 35 cc). It was evident that this was insufficient for a complete PVT analysis. Therefore Corelab were asked to recombine crude oil from the unsegregated sample with associated gas from the 31/2-7 oil zone test (bottle No. A3908). A complete analysis was performed on this sample and is reported in this document (RFLA 820292).

The 35 cc sample (bottle 9024-48) sufficed only for the pressure volume relationship and compositional analysis. This is reported in the Partial Fluid Study (RFLA 830015). The data obtained are very similar to those from the recombined crude sample and thus tend to confirm the validity of the full PVT analysis as reported in this report.


B. Reinholdtsen
Reservoir Engineer
A/S Norske Shell