

**EXXON** PRODUCTION RESEARCH COMPANY

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RESERVOIR DIVISION

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Gentlemen:

EPR.18PS.78 Hydrocarbon Report  
DST No. 1 Subsurface Oil Sample (Oil Zone)  
DST No. 2 Surface Separator Samples (Gas Zone)  
North Sea Well 15/9-1

This report presents the results of PVT and compositional tests made on a subsurface oil sample obtained under shut-in conditions on May 19, 1977, following the flow period of Drill Stem Test No. 1. The bubble point determined on this oil is 6200 psig at 244°F.

Also presented are the results of analyses made on separator gas and liquid samples obtained during a production test of the gas zone (Drill Stem Test No. 2) on May 23, 1977. Included are the compositional analyses of the produced fluids plus the results of dew point and depletion tests made at 241°F by use of a windowed cell. The compositions of the gases at several pressure levels in the depletion test, from 5700 to 1000 psig, were also determined.

Very truly yours,

C. C. MATTAX

By Robert H. Rossen  
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WFM/fa  
Attachment

EXXON PRODUCTION RESEARCH COMPANY

HYDROCARBON REPORT  
NORTH SEA WELL 15/9-1  
DST NO. 1 SUBSURFACE OIL SAMPLE (OIL ZONE)  
DST NO. 2 SURFACE SEPARATOR SAMPLES (GAS ZONE)

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SUBSURFACE OIL SAMPLE

NORTH SEA WELL 15/9-1 DST NO. 1

PERFORATIONS 11991-12008 FT. (OIL ZONE)

Subsurface Oil Sample  
North Sea Well 15/9-1 DST No. 1  
Perforated Interval 11991-12008 Feet

Oil Zone

DISCUSSION

A subsurface oil sample obtained on May 19, 1977 under shut-in conditions, by Flopetrol Inc., was transferred to Core Laboratories, Inc. shipping cylinder No. 1571 and was forwarded to the Exxon Production Research Company Hydrocarbon Laboratory for analysis. The results obtained are presented in this report.

EXAMINATION OF SUBSURFACE OIL SAMPLE

Source: Esso Exploration and Production Norway, North Sea Well 15/9-1  
DST No. 1, Perforations 11991-12008 feet (Oil Zone)  
Date Taken: May 19, 1977

Sampling Data

Sampling depth, ft 11800  
Pressure at sampling depth, psig  
Temperature at sampling depth, °F  
Well condition, period shut-in

Reservoir Data

Perforated Interval, feet 11,991-12,008  
Pressure, bottom of perforations, psig 6433  
Temperature, bottom of perforations, °F 244 (117.8°C)

Saturation Pressure

6200 psig at 244°F (117.8°C)

Properties of Samples

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TABLE I

Pressure-Volume Relations of Subsurface Oil Sample

Source: Esso Exploration and Production, Norway, North Sea Well 15/9-1 DST No. 1,  
Perforations 11991-12008 feet

Date Taken: May 19, 1977

Temperature: 244°F

<u>Pressure, psig</u>	<u>Relative Volume, V<sub>t</sub>/V<sub>bp</sub></u>	<u>*Y = <math>\frac{P_b - P}{P(\frac{V_t}{V_{bp}} - 1)}</math></u>
8000	0.9805	
7500	-0.9855	
7000	0.9902	
6495	0.9972	
6200 = P <sub>b</sub>	1.0000	
6035	1.0048	5.680
5795	1.0124	5.620
5570	1.0204	5.530
5255	1.0329	5.450
4915	1.0490	5.319
4620	1.0653	5.220
4365	1.0820	5.109
4040	1.1073	4.964
3690	1.1415	4.788
3540	1.1588	4.712
3165	1.2112	4.519
2880	1.2641	4.342
2590	1.3353	4.133
2370	1.3952	4.063
2135	1.4850	3.898
1945	1.5751	3.775
1660	1.7559	3.586
1460	1.9373	3.429
1270	2.1553	3.321
1020	2.5920	3.144
880	2.9553	3.040
680	3.7388	2.900
465	5.3586	2.741
370	6.6183	2.695

Specific volume at saturation pressure = 0.02299cu ft/lb

\*Calculated data for use in correcting subsurface oil sample

- P<sub>b</sub> = Bubble point or saturation pressure of sample at 244°F, psia  
P = Pressure below saturation pressure, psia  
V<sub>t</sub> = Two-phase relative volume factor at 244°F and P below P<sub>b</sub>  
V<sub>bp</sub> = Saturated oil relative volume at 244°F and 6215 psia ( 6200 psig)

TABLE II

Flash Liberation and Differential Liberation ResultsSubsurface Oil Sample

Source: Esso Exploration and Production, Norway, North Sea Well 15/9-1 DST No. 1, Perforations 11991-12008 feet

Date Taken: May 19, 1977

Properties of Saturated Oil: Temperature, °F 244 Saturation Pressure, psig 6200Gas Liberation and Shrinkage of Oil:  
(Flash)

Pressure (P <sub>1</sub> ), psig	Temperature, °F	R, Gas-Oil Ratio: cu ft at 60°F and 14.7 psia/bbl Residual Oil		Residual Oil Gravity, °API at 60°F	Specific Gravity Gas at 60°F (air = 1)	V <sub>r</sub> /V <sub>bp</sub>
		Flashed at P <sub>1</sub>	Flashed from P <sub>1</sub> to 0			
0	76	1103	-	24.0	0.8166	0.6308

(Differential at 244 °F)

Pressure, psig	Properties of Liberated Gas at 244°F and Indicated Pressure***		Gas-Oil Ratio: cu ft at 14.7 psia and 60°F/bbl Reservoir Oil at 6200 psig, 244 °F	Residual Oil Gravity, °API at 60°F	V**/V <sub>bp</sub>
	Compressibility, Z:	Viscosity, cp			
6200	-	-	0		1.0000
6000	1.064	0.0275	33		0.9866
5500	1.028	0.0262	99		0.9567
5000	0.992	0.0248	163		0.9297
4500	0.959	0.0248	223		0.9051
4000	0.930	0.0221	278		0.8795
3500	0.904	0.0208	330		0.8568
3000	0.888	0.0195	381		0.8356
2500	0.879	0.0180	431		0.8135
2000	0.884	0.0163	478		0.7937
1500	0.896	0.0149	526		0.7738
1000	0.916	0.0141	572		0.7545
500	0.944	0.0132	621		0.7353
100	0.973	0.0116	677		0.7095
0			687	24.8	0.7019

\*V<sub>r</sub> = Volume residual oil at 0 psig, 60°FV<sub>bp</sub> = Volume saturated oil at 6200 psig, 244°F

\*\*V = Volume saturated oil at indicated pressure, 244°F

\*\*\* = Determined from calculated composition of equilibrium gas



Comparison of Experimental and Computed Flash Liberation Results  
Subsurface Oil Sample

Source: Esso Exploration and Production, Norway, North Sea Well 15/9-1 DST No. 1, Perforations 11991-12008 feet

Date Taken: May 19, 1977

(P <sub>1</sub> ) Pressure psig	Temperature °F	Gas-Oil Ratio - cu ft/bbl Residual Oil		Residual Oil Gravity °API at 60°F		V <sub>r</sub> /V <sub>bp</sub> or 1/B <sub>oi</sub>			
		Flashed at P <sub>1</sub> Experimental	Flashed from P <sub>1</sub> to 0 Computed	Flashed from P <sub>1</sub> to 0 Experimental	Flashed from P <sub>1</sub> to 0 Computed	Experimental	Computed		
0	76	1103	1176	-	-	24.0	25.2	0.6308	0.6310
215*	100*	1057*	1055	-	73	26.2*	26.4	-	0.6433

Data Used in Flash Calculations

Subsurface Oil Sample		
Component	Mol %	gal/mol
Hydrogen Sulfide	Nil	-
Carbon Dioxide	4.21	6.37
Nitrogen	0.26	4.15
Methane	51.47	
Ethane	9.75	
Propane	4.84	
Iso-Butane	0.39	
N-Butane	1.87	
Iso-Pentane	0.47	
N-Pentane	0.31	
Hexanes Plus	26.43	36.77
Total	100.00	

K-value Source: NGAA (1957)  
Convergence Pressure: 10709 psia

Unadjusted Flash Data	
Molecular weight of heavier fraction	278
Density of heavier fraction, gm/cc at 60°F	0.9050
Specific volume of reservoir fluid at 6200 psig bubble point and 244 °F, cu ft/lb	0.02299
Mols per barrel	2.695
Alpha 1 = 1.1099	
Alpha 2 = 1.0444	

\*Field production test data

TABLE III

Hydrocarbon Analysis of Subsurface Oil Sample

Source: Esso Exploration and Production Norway, North Sea Well 15/9-1 DST No. 1  
Perforations 11991-12008 ft.

Date Taken: May 19, 1977

<u>Component</u>	<u>Mol%</u>	<u>Wt.%</u>
Carbon dioxide	4.21	2.04 v
Nitrogen	0.26	0.08
Methane	51.47	9.12
Ethane	9.75	3.23
Propane	4.84	2.35
iso-Butane	0.39	0.25
n-Butane	1.87	1.20
iso-Pentane	0.47	0.38
n-Pentane	0.31	0.24
Hexanes Plus	<u>26.43</u>	<u>81.11</u>
	100.00	100.00

## Hexanes Plus:

Density at 60°F = 0.9050 gms/ml

°API @ 60°F = 24.7

Molecular weight = 278

Because of the limited amount of sample available, and because of the low concentration of the C<sub>6</sub> to C<sub>9</sub> components in it, the hydrocarbon C<sub>6</sub> to C<sub>10</sub><sup>+</sup> distribution was not obtained.

TABLE IV

Viscosity of Reservoir Oil at 244° F

Source: Esso Exploration and Production Norway, North Sea  
Well 15/9-1 DST #1, 11991-12008 feet perforations

Date Taken: May 19, 1977

<u>Pressure, psig</u>	<u>Viscosity, cp</u>	<u>Density, gm/cc</u>
8000	0.260	0.7105
7500	0.240	0.7068
7000	0.224	0.7034
6500	0.210	0.7000
6200 = P <sub>b</sub>	0.202	0.6966
6000	0.211	0.7012
5500	0.233	0.7128
5000	0.261	0.7243
4500	0.292	0.7359
4000	0.323	0.7475
3500	0.370	0.7591
3000	0.435	0.7706
2500	0.500	0.7822
2000	0.588	0.7938
1500	0.714	0.8054
1000	0.952	0.8169
500	1.429	0.8285
0	2.793	0.8401

SURFACE SEPARATOR GAS AND LIQUID SAMPLES

NORTH SEA WELL 15/9-1 DST NO. 2

PERFORATIONS 11818-11835 FT. (GAS ZONE)

Surface Separator Gas and Liquid Samples  
North Sea Well 15/9-1 DST No. 2  
Perforations 11818-11835 feet (Gas Zone)

DISCUSSION

Objectives of Laboratory Work

The objectives of the laboratory work performed on separator gas and liquid samples taken during the North Sea Well 15/9-1 DST No. 2 production test of May 23, 1977, were as follows:

1. To determine the composition of the separator gas and liquid samples and to calculate the full well stream composition.
2. To determine the shrinkage of the separator liquid when flashed to ambient conditions.
3. To physically recombine the separator gas and liquid samples in their produced proportions and to determine the dew point pressure of the recombined sample at the reservoir temperature. To measure the liquid volumes condensed in the constant composition system to serve as K-value check points.
4. To measure gas and liquid volumes in the constant volume system to be used as K-value check points during a simulated reservoir depletion process.
5. To obtain the composition of the reservoir gas produced at several pressures during a depletion test - to 1000 psig.

Field Testing and Sampling

The separator gas and liquid samples were obtained by Esso Exploration and Production Norway during a production test of the North Sea Well 15/9-1 DST No. 2 on May 23, 1977. The separator conditions were 525 psig and 80°F. The separator gas production rate was 25.90 MMscfd. The saturated separator liquid production was 916 barrels at 80°F and 525 psig per day. The field data is summarized in Table V.

Laboratory Determinations and Results

1. A hydrocarbon analysis was made of the separator liquid using fractional distillation and chromatographic techniques. The cuts for the hexane through nonane fractions were made at the mid-boiling points of the normal components and molecular weights and densities were measured on the obtained fractions. The results of this analysis in weight percent are presented in Table VI. (Table VII lists the equivalent mol percent analysis.)

2. An analysis of the separator gas was made using chromatographic techniques. These results are also given in Table VI together with the composition of the full well stream as determined by mathematically recombining the gas and liquid compositions in their produced ratio.
3. An equilibrium flash of the separator liquid to ambient conditions was made, and the experimental results of this flash are compared in Table VII with the results obtained by calculation from the separator liquid composition. The experimental flash data were used to calculate the density of the saturated separator liquid at metering conditions and the shrinkage of the separator liquid to stock tank conditions. The shrinkage value obtained was used with the separator liquid production rate to calculate the stock tank liquid production. The separator and stock tank liquid production rates and the resulting gas/condensate ratios are given in Table V.
4. Separator gas and liquid were physically recombined in a windowed cell in their produced proportions and the contents were heated to the reservoir temperature of 241°F. Measurements of gas and liquid volumes were made as the pressure of the system was incrementally increased to the dew point pressure where the liquid was entirely vaporized. An extrapolation of a plot of liquid volume percent versus pressure and visual observation of the disappearance of the last trace of liquid were used in determining the dew point pressure. Table VIII presents the data obtained. Table VIII also presents the compressibility factors,  $Z$ , at pressures above the dew point. Fig. 1 presents a plot of the liquid volume percent versus pressures at 241°F obtained from this test.
5. The pressure on the contents of the windowed cell at 241°F was lowered from the dew point pressure of 5700 psig by slow bleeding of a portion of the gas phase, thus simulating the reservoir depletion process. Measurements of the equilibrium liquid and gas volumes were made at several pressures during the test. The results of this investigation are given in Table IX and are also plotted in Fig. 1. The compositions of the gas and liquid phases remaining at the final depletion pressure of 1000 psig at 241°F were determined and are presented in Table X.
6. Also determined were the compositions of the gas phase produced in the depletion test at several pressures between the dew point pressure of 5700 psig and the final depletion pressure of 1000 psig. These results are given in Table XI.

TABLE V

Field Production Data

Source:	Esso Exploration and Production, Norway, North Sea Well 15/9-1 DST No. 2, 11818-11835 feet (Gas Zone)
Date of Test:	May 23, 1977
Reservoir Temperature, °F	241
Flowing Tubing Pressure, psig	1365
Flowing Tubing Temperature, °F	63
Separator Pressure, psig	525
Separator Temperature, °F	80
Separator Liquid Production, bbl at 525 psig & 80°F/day	916
* Stock-Tank Liquid Production, bbl at 60° F/day	746
Separator Gas Production, cu ft/day at 14.7 psia and 60° F	25,900,000
Gas/Separator Liquid Ratio, cu ft/bbl	28280
bbl/MMcf	35.4
Gas/Stock-Tank Liquid Ratio, cu ft/bbl	34700
bbl/MMcf	28.8

NOTE: Stock-tank liquid and separator liquid production is on a water-free basis.

\*The stock-tank liquid production is obtained from the field measured separator liquid production and the laboratory determined shrinkage of 0.8142 shown in Table VII.

TABLE VI

Hydrocarbon Analyses of Separator Gas and Liquid Samples  
and Composite Well Stream

Source: Esso Exploration and Production, Norway, North Sea Well 15/9-1  
DST #2, 11818-11835 Ft. (Gas Zone)

Date Taken: May 23, 1977

Separator Conditions

Pressure, psig 525  
Temperature, °F 80

Component	Separator Liquid			Separator Gas	* Composite Well Stream
	Weight %	Density g/cc at 60° F	Molecular Weight	Mol %	Mol %
Hydrogen Sulfide	0.00			0.00	0.00
Carbon Dioxide	0.77			5.79	5.67
Nitrogen	0.03			0.53	0.52
Methane	1.71			80.98	78.84
Ethane	1.65			7.56	7.51
Propane	3.25			3.33	3.47
Iso-Butane	1.46			0.43	0.50
N-Butane	3.49			0.72	0.90
Iso-Pentane	2.21			0.16	0.26
N-Pentane	2.86			0.16	0.29
Hexanes	7.03	0.7089	89	0.18	0.44
Heptanes	10.11	0.7456	99	0.10	0.44
Octanes	9.86	0.7722	110	0.04	0.34
Nonanes	7.32	0.7905	122	0.01	0.21
Heavier Fractions	48.25	0.8455	270	0.01	0.61
Total	100.00			100.00	100.00
Pentane-Free Fraction		0.7557	102		
Experimental Separator Gas Gravity (Air = 1)				0.7111	

\*Composite wellstream is calculated by use of the field measured ratio of 28280 standard cu. ft. of separator gas per barrel of separator liquid at 525 psig and 80°F.



TABLE VII

Comparison of Experimental and Computed Flash Liberation Results  
Separator Liquid Sample

Source: Esso Exploration and Production, Norway, North Sea Well 15/9-1 DST #2, 11818-11835 ft. (Gas Zone)

Date Taken: May 23, 1977

(P <sub>1</sub> ) Pressure psig	Temperature °F	Gas-Oil Ratio - cu ft/bbl Residual Oil		Residual Oil Gravity °API at 60°F		V <sub>r</sub> /V <sub>bp</sub> or 1/B <sub>oi</sub>	
		Flashed at P <sub>1</sub> Experimental	Flashed from P <sub>1</sub> to 0 Computed	Experimental	Computed	Experimental	Computed
0	76	389	-	45.6		0.8142	
0	81		386		46.6		0.8141

Data Used in Flash Calculations

Separator Liquid Sample

Component	Mol %	gal/mol
Hydrogen Sulfide	0.00	
Carbon Dioxide	1.91	9.09
Nitrogen	0.11	7.63
Methane	11.59	
Ethane	5.97	
Propane	8.02	
Iso-Butane	2.74	
N-Butane	6.54	
Iso-Pentane	3.33	
N-Pentane	4.32	
Hexanes	8.60	15.04
Heptanes	11.12	15.91
Octanes	9.76	17.07
Nonanes	6.53	18.49
Heavier Fraction	19.46	38.27
TOTAL	100.00	

K-value Source: NGAA (1957)

Convergence Pressure: 5000 psia

Unadjusted Flash Data

Molecular weight of heavier fraction	270
Density of heavier fraction, gm/cc at 60°F	0.8455
Specific volume of separator fluid at 525 psig bubble point and 80 °F, cu ft/lb	0.02172
Mols per barrel	2.374

NOTE: 81°F K-values and +2% change in density of heavier fractions were used to obtain the above computed checks.

TABLE VIII

Data for Determination of Dew Point at 241°F  
(Constant Composition)

Source: Esso Exploration and Production Norway, North Sea Well 15/9-1  
DST No. 2, 11818-11835 feet (Gas Zone)

Date Taken: May 23, 1977

<u>Pressure,</u> <u>psig</u>	<u>Equilibrium Volumes</u> <u>at 241°F and</u> <u>Indicated Pressure</u>		<u>Volume Percent</u> <u>Liquid Phase</u> <u>at 241°F and</u> <u>Indicated Pressure</u>	<u>Compressibility</u> <u>Factor, Z,</u> <u>at 241°F and</u> <u>Indicated Pressure</u>
	<u>Gas</u> <u>cu. cm.</u>	<u>Liquid</u> <u>cu. cm.</u>		
6600	101.110	0.	0.	1.041
6300	103.348	0.	0.	1.015
6000	106.424	0.	0.	0.996
5700 = Dew Point	110.340	0.000	0.000	0.981
5500	113.076	0.061	0.054	
5300	116.052	0.162	0.139	
5000	121.464	0.344	0.282	
4600	130.089	0.670	0.512	
4200	139.201	1.068	0.761	
3700	155.174	1.598	1.019	
3200	172.597	2.077	1.189	
2700	203.776	2.505	1.214	
2300	237.336	2.790	1.162	
1600	344.240	3.015	0.868	
1220	460.259	3.076	0.664	

Charge to windowed cell:

Separator Gas = 31,448 ml at 60°F and 14.7 psia

Separator Liquid = 6.244 ml at 80°F and 525 psig

Recombining Ratio = 28,280 cubic feet separator gas at 60°F,  
14.7 psia per barrel separator liquid at 80°F and 525 psig

Z = PV/NRT

TABLE IX

Volumes of Equilibrium Phases at 241°F During Pressure Depletion  
(Constant Volume)

Source: Esso Exploration and Production Norway, North Sea Well 15/9-1  
DST No. 2, 11818-11835 feet (Gas Zone)

Date Taken: May 23, 1977

Pressure,* psig	Equilibrium Volumes at 241°F and Indicated Pressure		Volume Percent Liquid Phase at 241°F and Indicated Pressure
	Gas, cu. cm.	Liquid, cu. cm.	
5700 = Dew Point	110.340	0.000	0.000
4600	109.721	0.619	0.561
4200	109.293	1.047	0.949
3500	108.681	1.659	1.504
2940	108.294	2.046	1.854
2430	107.998	2.342	2.123
1890	107.957	2.383	2.160
1475	108.079	2.261	2.049
1000	108.273	2.067	1.873

\*Pressures below the dew point pressure were reached by slow bleeding of gas from the windowed cell, thus simulating the reservoir depletion process.

TABLE X

Composition of Equilibrium Gas and Liquid Remaining at  
1000 psig\* and 241°F from the Pressure Depletion Test

Source: Esso Exploration and Production, Norway, North Sea Well 15/9-1 DST No. 2,  
11818-11835 feet (Gas Zone)

Date Taken: May 23, 1977

Component	Equilibrium Composition Mol %		Experimental 1000 psig, 241°F K-Values
	Gas	Liquid	
Hydrogen Sulfide	0.00	0.00	-
Carbon Dioxide	5.70	1.96	2.91
Nitrogen	0.52	0.04	13.0
Methane	79.53	17.37	4.58
Ethane	7.57	4.95	1.53
Propane	3.50	4.51	0.78
Iso-Butane	0.42	0.92	0.46
N-Butane	0.77	2.10	0.37
Iso-Pentane	0.22	0.99	0.22
N-Pentane	0.24	1.20	0.20
Heavier Fraction (C <sub>6</sub> +) <u></u>	<u>1.53</u>	<u>65.96</u>	0.023 (C <sub>6</sub> +) <u></u>
Total	100.00	100.00	

\*The pressure of 1000 psig was reached by slow bleeding of gas from the windowed cell starting at the dew point pressure of 5700 psig.

TABLE XI

Mol Percent Hydrocarbon Analyses of Gas Phase  
During Pressure Depletion at 241°F

(Depletion at constant volume starting at 5700 psig)

Source: Esso Exploration and Production, Norway, North Sea Well 15/9-1  
DST No. 2, 11818-11835 ft. (Gas Zone)

Date Taken: May 23, 1977

<u>Component</u>	<u>5700</u>	<u>4600</u>	<u>4200</u>	<u>3500</u>	<u>2940</u>	<u>2430</u>	<u>1890</u>	<u>1475</u>	<u>1000</u>
Hydrogen Sulfide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbon Dioxide	5.67	5.67	5.67	5.67	5.67	5.68	5.69	5.70	5.70
Nitrogen	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.53	0.52
Methane	78.84	79.05	79.13	79.33	79.45	79.56	79.63	79.61	79.53
Ethane	7.51	7.53	7.54	7.53	7.54	7.54	7.55	7.55	7.57
Propane	3.47	3.48	3.48	3.47	3.47	3.47	3.47	3.48	3.50
Iso-Butane	0.50	0.47	0.46	0.44	0.43	0.42	0.42	0.42	0.42
N-Butane	0.90	0.84	0.82	0.79	0.77	0.77	0.76	0.76	0.77
Iso-Pentane	0.26	0.24	0.24	0.23	0.22	0.22	0.22	0.22	0.22
N-Pentane	0.29	0.27	0.26	0.25	0.25	0.24	0.24	0.24	0.24
Heavier Fraction	2.04	1.93	1.88	1.77	1.68	1.58	1.50	1.49	1.53
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

FIGURE 1

Liquid Volume Percent vs Pressure at 241°F

Source: Esso Exploration and Production Norway, North Sea Well 15/9-1 DST No. 2,  
11818-11835 feet, Gas Zone

Date Taken: May 23, 1977

