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# Reservoir Fluid Study

STATOIL
15/8-1 Well DST 1C
Sleipner Field
Norway

RFL 830489

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**CORE LABORATORIES, INC.**

September 30, 1983

P. L. Moses
Manager
Reservoir Fluid Analysis

STATOIL
FORUS
P. O. Box 300
N-4001 Stavanger
Norway

Attention: Mr. J. Grande

Subject: Reservoir Fluid Study
15/8-1 Well DST 1C
Sleipner Field
Norway
RFL 830489

Gentlemen:

Samples of separator gas and liquid collected from the subject well by your representatives on December 3, 1981, were forwarded to our laboratory for use in a reservoir fluid study. The results of the study are presented in this report.

The opening pressures of the separator gas cylinders and the saturation pressure of the separator liquid were measured at ambient, laboratory temperature. These measurements were compared to the reported, sampling conditions to provide a quality control check. A summary of the samples received in the laboratory may be found on page two.

The compositions of the separator gas samples were measured through nonanes with decanes plus fractions by a combination of routine gas and temperature-programmed chromatography. The results of these analyses may be found on pages three and four. The composition of the separator liquid was determined through hexanes by low-temperature, fractional distillation and gas chromatography. The heptanes plus fraction was then analyzed to an eicosanes plus fraction by temperature-programmed chromatography. These data are shown on pages five and six.

The producing gas/liquid ratio was 7417 cubic feet of primary separator gas at 14.73 psia and 60°F. per barrel of stock tank liquid. In the laboratory, this was found to be equivalent to 3700 standard cubic feet of primary separator gas per barrel of primary separator liquid at 515 psig and 88°F. The separator products were physically recombined to the latter ratio. A portion of the recombined fluid was charged to a high pressure, windowed cell at reservoir temperature (275°F.). Visual examination revealed that the fluid contained what appeared to be

drilling mud (approximately 10 percent by volume). This contamination was traced to the separator liquid sample. Due to a shortage of separator liquid, it was necessary to reproduce the liquid in the laboratory by flashing the contaminated, recombined fluid back through a separator operating at 515 psig and 88°F. The contaminant was then allowed to precipitate from the liquid. The "clean" separator liquid was then displaced into a mixing cylinder and recombined with the separator gas. The resulting fluid was used in the remainder of the study. The composition of the well stream, also shown on page five, was calculated based on the measured compositions of the separator products and the recombination ratio. Please note that the well stream composition differs from that reported via telex on September 2, 1983, which was calculated using the composition of the contaminated separator liquid.

A portion of the recombined fluid was charged to a high pressure, windowed cell at reservoir temperature (275°F.). During a constant composition expansion at this temperature, a retrograde dew point was observed at 3678 psig which is significantly below the reported reservoir pressure of 7711 psig. The pressure-volume relations are presented on page seven.

A constant volume depletion at reservoir temperature was performed on the fluid. Starting at saturation pressure, a sample of fluid was expanded to the first depletion pressure and equilibrated. The resulting gas phase was displaced from the cell at constant pressure until original sample volume was obtained. The volume, deviation factor and composition of the produced gas were determined. The remaining system was then expanded to the second depletion pressure, the gas phase produced back to constant volume, and the produced gas analyzed. This procedure was repeated until the reservoir pressure was depleted to 700 psig. The 700 psig equilibrium liquid phase was then analyzed. A tabulation of these data may be found on page eight; graphic interpretations are provided on pages twelve and thirteen.

Flash calculations were performed to determine the recoverable tank liquid and separator gas as functions of reservoir pressure. A 100 percent plant efficiency was assumed. The results of these calculations are shown on pages nine and ten.

During the depletion, retrograde liquid volume was measured visually. The maximum liquid volume observed was 7.2 percent of the hydrocarbon pore space. These data are presented in tabular and graphic formats on pages eleven and sixteen, respectively.

Thank you for the opportunity to perform this study for STATOIL. Should you have any questions concerning these data, or if we may be of further service, please do not hesitate to contact us.

Very truly yours,

CORE LABORATORIES, INC.

James R. Fortner

James R. Fortner
Area Manager
Reservoir Fluid Analysis

JRF:RSR:mc
10 cc: Addressee

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Howe Moss Road
Kirkhill Industrial Estate
Dyce, AB2 OES Aberdeen Scotland
Attn: Mr. Les Sebborn

**CORE LABORATORIES, INC.**
*Reservoir Fluid Analysis*



File RFL 830489

Company STATOIL Date Sampled December 3, 1981

Well 15/8-1 DST 1C State

Field Sleipner Country Norway

## FORMATION CHARACTERISTICS

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

## WELL CHARACTERISTICS

| | |
|---|---|
| Elevation | Ft. |
| Total Depth | Ft. |
| Producing Interval | Ft. |
| Tubing Size and Depth | In. to Ft. |
| Open Flow Potential | MMSCF/Day |
| Last Reservoir Pressure | 7711 PSIG @ Ft. |
| Date | |
| Reservoir Temperature | 275 °F. @ Ft. |
| Status of Well | |
| Pressure Gauge | |

## SAMPLING CONDITIONS

| | | |
|---|---|---|
| Flowing Tubing Pressure | | 1860 PSIG @ 128°F. |
| Flowing Bottom Hole Pressure | | PSIG |
| Primary Separator Pressure | | 515 PSIG |
| Primary Separator Temperature | | 88 °F. |
| Secondary Separator Pressure | | PSIG |
| Secondary Separator Temperature | | °F. |
| Field Stock Tank Liquid Gravity | | °API @ 60°F. |
| Primary Separator Gas Production Rate | | MSCF/Day |
| Pressure Base | 14.73 PSIA | |
| Temperature Base | 60 °F. | |
| Compressibility Factor ($F_{pv}$) | | |
| Gas Gravity (Laboratory) | | |
| Gas Gravity Factor ($F_g$) | | |
| Liquid Production Rate @ 60°F. | | Bbls/Day |
| Primary Separator Gas/Stock Tank Liquid Ratio | | 7417 SCF/Bbl |
| | or | 134.88 Bbls/MMSCF |

Sampled by

REMARKS:

## SUMMARY OF SAMPLES RECEIVED IN LABORATORY

### Separator Gas

| | Separator Conditions | | Laboratory Opening Conditions | |
|---|---|---|---|---|
| Cylinder Number | Pressure, PSIG | Temperature, °F. | Pressure, PSIG | Temperature, °F. |
| 001-108 | 515* | 88 | 520 | 70 |
| 001-102 | 515** | 88 | 540 | 70 |

### Separator Liquid

| | Separator Conditions | | Laboratory Bubble Point Pressure | |
|---|---|---|---|---|
| Cylinder Number | Pressure, PSIG | Temperature, °F. | Pressure, PSIG | Temperature, °F. |
| 001-I | 515 | 88 | 513 | 71 |

*Cylinder tag indicated sampling pressure = 560 psig.
**Cylinder tag indicated sampling pressure = 595 psig.

## HYDROCARBON ANALYSIS OF SEPARATOR GAS SAMPLE

| Component | Mol Percent | GPM |
|---|---|---|
| Hydrogen Sulfide | 0.00 | |
| Carbon Dioxide | 9.43 | |
| Nitrogen | 3.02 | |
| Methane | 65.00 | |
| Ethane | 10.71 | 2.863 |
| Propane | 8.75 | 2.407 |
| iso-Butane | 1.23 | 0.402 |
| n-Butane | 1.26 | 0.397 |
| iso-Pentane | 0.28 | 0.102 |
| n-Pentane | 0.17 | 0.062 |
| Hexanes | 0.09 | 0.037 |
| Heptanes | 0.04 | 0.016 |
| Octanes | 0.02 | 0.009 |
| Nonanes | Trace | 0.000 |
| Decanes plus | Trace | 0.000 |
| | 100.00 | 6.295 |

Calculated gas gravity (air = 1.000) = 0.843

Calculated gross heating value = 1176 BTU per cubic foot of dry gas at 14.73 psia and 60°F.

Collected at 515 psig and 88°F.

Cylinder: 001-108

## HYDROCARBON ANALYSIS OF SEPARATOR GAS SAMPLE

| Component | Mol Percent | GPM |
|---|---|---|
| Hydrogen Sulfide | 0.00 | |
| Carbon Dioxide | 9.40 | |
| Nitrogen | 2.99 | |
| Methane | 64.93 | |
| Ethane | 10.70 | 2.860 |
| Propane | 8.78 | 2.416 |
| iso-Butane | 1.24 | 0.405 |
| n-Butane | 1.29 | 0.407 |
| iso-Pentane | 0.30 | 0.110 |
| n-Pentane | 0.19 | 0.069 |
| Hexanes | 0.11 | 0.045 |
| Heptanes | 0.05 | 0.021 |
| Octanes | 0.02 | 0.009 |
| Nonanes | Trace | 0.000 |
| Decanes plus | Trace | 0.000 |
| | 100.00 | 6.342 |

Calculated gas gravity (air = 1.000) = 0.845

Calculated gross heating value = 1180 BTU per cubic foot of dry gas at 14.73 psia and 60°F.

Collected at 515 psig and 88°F.

Cylinder: 001-102

## HYDROCARBON ANALYSES OF SEPARATOR PRODUCTS AND CALCULATED WELL STREAM

| Component | Separator Liquid, Mol Percent | Separator Gas, Mol Percent | Well Stream Mol Percent | Well Stream GPM |
|---|---|---|---|---|
| Hydrogen Sulfide | 0.00 | 0.00 | 0.00 | |
| Carbon Dioxide | 4.10 | 9.40 | 8.09 | |
| Nitrogen | 0.24 | 2.99 | 2.31 | |
| Methane | 13.61 | 64.93 | 52.26 | |
| Ethane | 10.38 | 10.70 | 10.62 | 2.839 |
| Propane | 22.92 | 8.78 | 12.27 | 3.375 |
| iso-Butane | 6.47 | 1.24 | 2.53 | 0.827 |
| n-Butane | 9.14 | 1.29 | 3.23 | 1.018 |
| iso-Pentane | 4.35 | 0.30 | 1.30 | 0.476 |
| n-Pentane | 3.75 | 0.19 | 1.07 | 0.387 |
| Hexanes | 4.84 | 0.11 | 1.28 | 0.522 |
| Heptanes | 4.22 | 0.05 | 1.08 | 2.592* |
| Octanes | 5.37 | 0.02 | 1.34 | |
| Nonanes | 3.20 | Trace | 0.79 | |
| Decanes plus | 7.41 | Trace | 1.83 | |
| | 100.00 | 100.00 | 100.00 | 12.036 |
| **Properties of Heptanes plus** | | | | |
| API gravity @ 60°F. | 38.5 | | | |
| Density, Gm/Cc @ 60°F. | 0.8315 | | 0.831 | |
| Molecular weight | 135 | 103 | 135 | |

Calculated separator gas gravity (air=1.000) = 0.845
Calculated gross heating value for separator gas = 1180 BTU per cubic foot of dry gas @ 14.73 psia and 60°F.

Primary separator gas collected @ 515 psig and 88°F.
Primary separator liquid collected @ 515 psig and 88°F.

Primary separator gas/separator liquid ratio = 3700 SCF/Bbl @ 88°F.
Primary separator liquid/stock tank liquid ratio = 2.0046 Bbls @ 88°F./Bbl
Primary separator gas/well stream ratio = 753.11 MSCF/MMSCF
Stock tank liquid/well stream ratio = 101.54 Bbls/MMSCF

*GPM value for heptanes plus fraction

## HYDROCARBON ANALYSIS OF SEPARATOR LIQUID HEPTANES PLUS FRACTION

| Component | Weight Percent | Mol Percent |
|---|---|---|
| Propane | 0.00 | 0.00 |
| Butanes | 0.00 | 0.00 |
| Pentanes | 0.00 | 0.00 |
| Hexanes | 0.00 | 0.00 |
| Methyl-Cyclopentane | 2.56 | 4.08 |
| Benzene | 0.00 | 0.00 |
| Cyclohexane | 4.08 | 6.51 |
| Heptanes | 8.26 | 11.07 |
| Methyl-Cyclohexane | 8.26 | 11.29 |
| Toluene | 5.14 | 7.49 |
| Octanes | 7.75 | 9.11 |
| Ethylbenzene | 0.97 | 1.23 |
| Meta & Para Xylenes | 6.26 | 7.92 |
| Orthoxylene | 1.57 | 1.99 |
| Nonanes | 5.44 | 5.69 |
| iso-Propyl Benzene | 0.35 | 0.39 |
| n-Propyl Benzene | 0.40 | 0.45 |
| 1,2,4 Trimethylbenzene | 2.32 | 2.59 |
| Decanes | 7.40 | 6.98 |
| Undecanes | 5.91 | 5.08 |
| Dodecanes | 3.49 | 2.75 |
| Tridecanes | 4.08 | 2.97 |
| Tetradecanes | 3.91 | 2.65 |
| Pentadecanes | 3.47 | 2.19 |
| Hexadecanes | 2.62 | 1.55 |
| Heptadecanes | 1.83 | 1.02 |
| Octadecanes | 1.59 | 0.84 |
| Nonadecanes | 1.33 | 0.67 |
| Eicosanes plus | 11.01 | 3.49 |
| | 100.00 | 100.00 |

Calculated average molecular weight = 134

## DEPLETION STUDY AT 275°F.

Hydrocarbon Analyses of Produced Well Stream - Mol Percent

| | Reservoir Pressure - PSIG | | | | | | |
|---|---|---|---|---|---|---|---|
| Component | 3678 | 3000 | 2400 | 1800 | 1200 | 700 | 700* |
| Carbon Dioxide | 8.10 | 8.15 | 8.26 | 8.34 | 8.47 | 8.40 | 2.06 |
| Nitrogen | 2.32 | 2.34 | 2.40 | 2.45 | 2.43 | 2.39 | 0.20 |
| Methane | 52.29 | 53.54 | 54.24 | 54.64 | 54.38 | 53.63 | 8.47 |
| Ethane | 10.62 | 10.66 | 10.73 | 10.81 | 10.93 | 11.02 | 4.32 |
| Propane | 12.27 | 12.20 | 12.13 | 12.15 | 12.37 | 12.74 | 9.26 |
| iso-Butane | 2.53 | 2.49 | 2.45 | 2.44 | 2.49 | 2.60 | 2.92 |
| n-Butane | 3.23 | 3.10 | 3.08 | 3.07 | 3.22 | 3.33 | 4.35 |
| iso-Pentane | 1.30 | 1.24 | 1.21 | 1.20 | 1.20 | 1.30 | 2.82 |
| n-Pentane | 1.07 | 0.99 | 0.98 | 0.98 | 0.97 | 1.08 | 2.60 |
| Hexanes | 1.26 | 1.17 | 1.10 | 1.06 | 1.05 | 1.14 | 5.02 |
| Heptanes plus | 5.01 | 4.12 | 3.42 | 2.86 | 2.49 | 2.37 | 57.98 |
| | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Molecular weight of heptanes plus | 135 | 124 | 119 | 114 | 110 | 109 | 159 |
| Density of heptanes plus | 0.831 | 0.821 | 0.815 | 0.810 | 0.805 | 0.804 | 0.856 |
| Equilibrium gas | 0.842 | 0.797 | 0.792 | 0.814 | 0.862 | 0.912 | |
| Two-phase | 0.842 | 0.788 | 0.768 | 0.770 | 0.779 | 0.782 | |
| Well Stream produced- Cumulative percent of initial | 0 | 12.822 | 28.424 | 46.361 | 64.494 | 79.130 | |

*Composition of 700 psig equilibrium liquid phase.

## PRESSURE-VOLUME RELATIONS OF RESERVOIR FLUID AT 275°F.
## (Constant Composition Expansion)

| Pressure, PSIG | | Relative Volume | Deviation Factor, Z |
|---|---|---|---|
| 8000 | | 0.7316 | 1.337 |
| 7711 | Reservoir Pressure | 0.7398 | 1.303 (1) |
| 7500 | | 0.7460 | 1.278 |
| 7000 | | 0.7634 | 1.221 |
| 6500 | | 0.7810 | 1.160 |
| 6000 | | 0.8029 | 1.101 |
| 5500 | | 0.8292 | 1.043 |
| 5000 | | 0.8611 | 0.985 |
| 4500 | | 0.9014 | 0.928 |
| 4200 | | 0.9317 | 0.896 |
| 4000 | | 0.9549 | 0.875 |
| 3900 | | 0.9681 | 0.864 |
| 3800 | | 0.9818 | 0.854 |
| 3700 | | 0.9965 | 0.844 |
| 3678 | Dew Point | 1.0000 | 0.842 (2) |
| 3600 | | 1.0126 | |
| 3500 | | 1.0297 | |
| 3350 | | 1.0590 | |
| 3150 | | 1.1058 | |
| 2900 | | 1.1778 | |
| 2600 | | 1.2937 | |
| 2300 | | 1.4510 | |
| 1893 | | 1.7768 | |
| 1620 | | 2.0980 | |
| 1428 | | 2.4142 | |
| 1277 | | 2.7306 | |
| 1152 | | 3.0621 | |

(1) Gas expansion factor = 1.599 MSCF/Bbl
(2) Gas expansion factor = 1.183 MSCF/Bbl

## CALCULATED CUMULATIVE RECOVERY DURING DEPLETION

| Cumulative Recovery per MMSCF of Original Fluid | Initial in Place | Reservoir Pressure - PSIG 3678 | 3000 | 2400 | 1800 | 1200 | 700 |
|---|---|---|---|---|---|---|---|
| Well Stream - MSCF | 1000 | 0 | 128.22 | 284.24 | 463.61 | 644.94 | 791.30 |
| Normal Temperature Separation | | | | | | | |
| Stock Tank Liquid - Barrels | 92.99 | 0 | 9.61 | 19.47 | 29.16 | 37.89 | 44.93 |
| Primary Separator Gas-MSCF | 791.38 | 0 | 104.74 | 235.08 | 387.37 | 542.23 | 666.03 |
| Stock Tank Gas - MSCF | 120.02 | 0 | 13.84 | 29.39 | 46.24 | 63.32 | 78.26 |
| Total "Plant Products" in Primary Separator Gas-Gallons | | | | | | | |
| Ethane | 2365 | 0 | 312 | 702 | 1158 | 1627 | 2006 |
| Propane | 2115 | 0 | 286 | 646 | 1073 | 1518 | 1882 |
| Butanes (total) | 714 | 0 | 98 | 224 | 377 | 540 | 673 |
| Pentanes plus | 227 | 0 | 31 | 71 | 120 | 170 | 211 |
| Total "Plant Products" in Stock Tank Gas - Gallons | | | | | | | |
| Ethane | 458 | 0 | 52 | 108 | 168 | 227 | 279 |
| Propane | 1116 | 0 | 129 | 273 | 428 | 585 | 723 |
| Butanes (total) | 773 | 0 | 92 | 198 | 316 | 441 | 551 |
| Pentanes plus | 336 | 0 | 41 | 90 | 146 | 206 | 262 |
| Total "Plant Products" in Well Stream - Gallons | | | | | | | |
| Ethane | 2839 | 0 | 365 | 813 | 1331 | 1861 | 2292 |
| Propane | 3375 | 0 | 430 | 951 | 1550 | 2168 | 2680 |
| Butanes (total) | 1845 | 0 | 230 | 506 | 823 | 1154 | 1432 |
| Pentanes plus | 3953 | 0 | 418 | 859 | 1307 | 1724 | 2067 |

Primary separator at 515 psig and 88°F.; stock tank at 50°F.

## CALCULATED INSTANTANEOUS RECOVERY DURING DEPLETION

| | Reservoir Pressure - PSIG | | | | | |
|---|---|---|---|---|---|---|
| | 3678 | 3000 | 2400 | 1800 | 1200 | 700 |
| **Normal Temperature Separation** | | | | | | |
| Stock Tank Liquid Gravity, °API at 60°F. | 56.1 | 59.5 | 62.0 | 64.5 | 66.7 | 68.1 |
| Separator Gas/Well Stream Ratio, MSCF/MMSCF | | | | | | |
| Primary Separator Gas Only | 791.38 | 816.91 | 835.36 | 849.06 | 854.00 | 845.86 |
| Primary Stage Separator and Stock Tank Gases | 911.40 | 924.83 | 935.01 | 943.03 | 948.18 | 947.94 |
| Separator Gas/Stock Tank Liquid Ratio, SCF/STB | | | | | | |
| Primary Separator Gas Only | 8510 | 10897 | 13220 | 15722 | 17724 | 17595 |
| Primary Stage Separator and Stock Tank Gases | 9801 | 12336 | 14797 | 17462 | 19679 | 19718 |
| **GPM from Smooth Well Stream Compositions** | | | | | | |
| Ethane plus | 12.013 | 11.256 | 10.804 | 10.498 | 10.449 | 10.699 |
| Propane plus | 9.173 | 8.406 | 7.935 | 7.608 | 7.527 | 7.753 |
| Butanes plus | 5.798 | 5.050 | 4.598 | 4.265 | 4.124 | 4.248 |
| Pentanes plus | 3.953 | 3.259 | 2.827 | 2.500 | 2.295 | 2.349 |

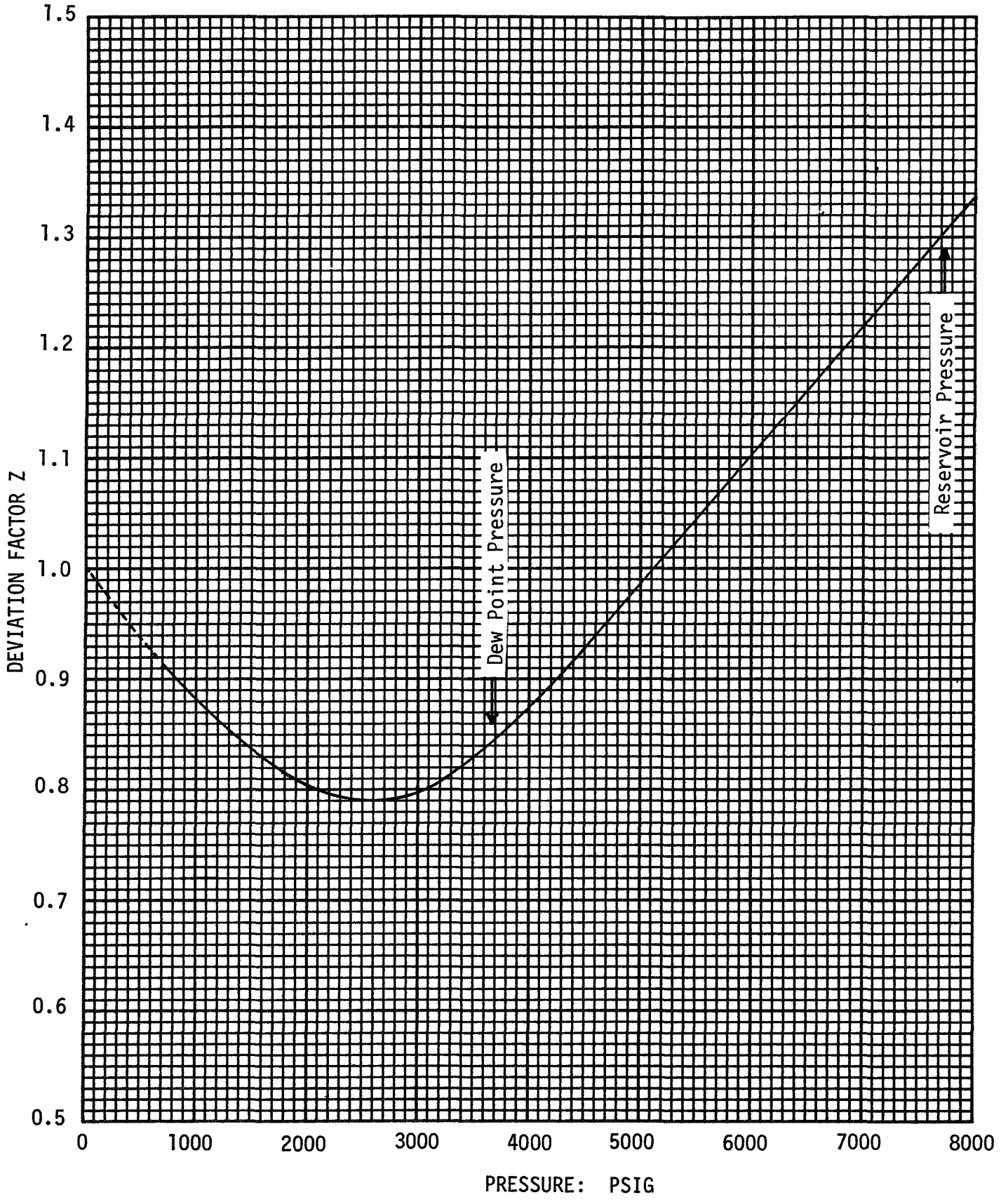
## RETROGRADE CONDENSATION DURING GAS DEPLETION AT 275°F.

| Pressure, PSIG | | Retrograde Liquid Volume, Percent of Hydrocarbon Pore Space |
|---|---|---|
| 3678 | Dew Point | 0.0 |
| 3600 | | 0.1 |
| 3500 | | 0.2 |
| 3350 | | 0.4 |
| 3150 | | 0.7 |
| 3000 | First Depletion Pressure | 1.6 |
| 2400 | | 5.7 |
| 1800 | | 7.2 |
| 1200 | | 7.1 |
| 700 | | 6.1 |
| 0 | | 3.7 |

# DEVIATION FACTOR OF GAS PHASE DURING DEPLETION

Company STATOIL
Well 15/8-1 DST 1C
Field SLEIPNER

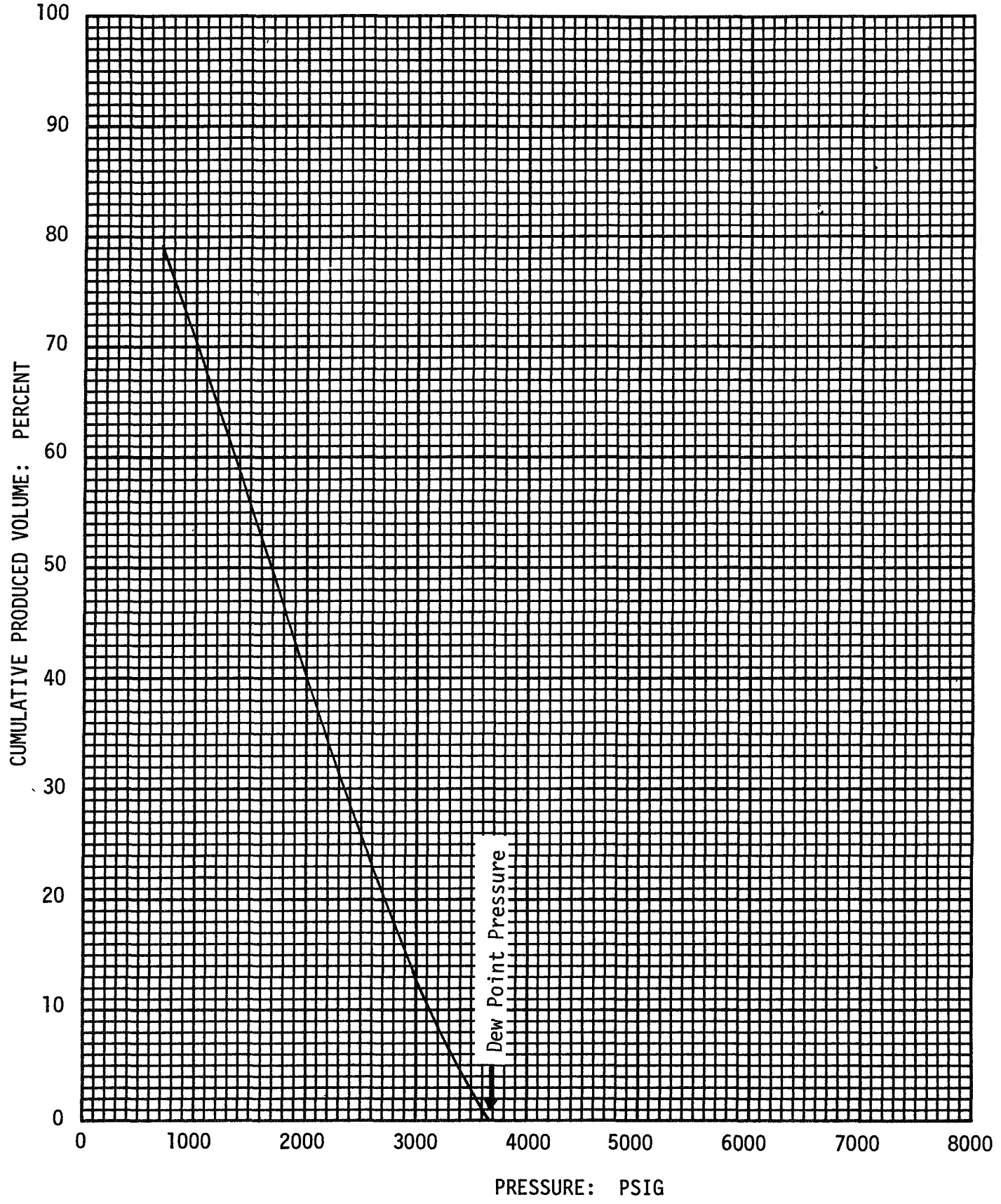
Formation
State
Country NORWAY



# CUMULATIVE PRODUCED VOLUME DURING DEPLETION

Company STATOIL
Well 15/8-1 DST 1C
Field SLEIPNER

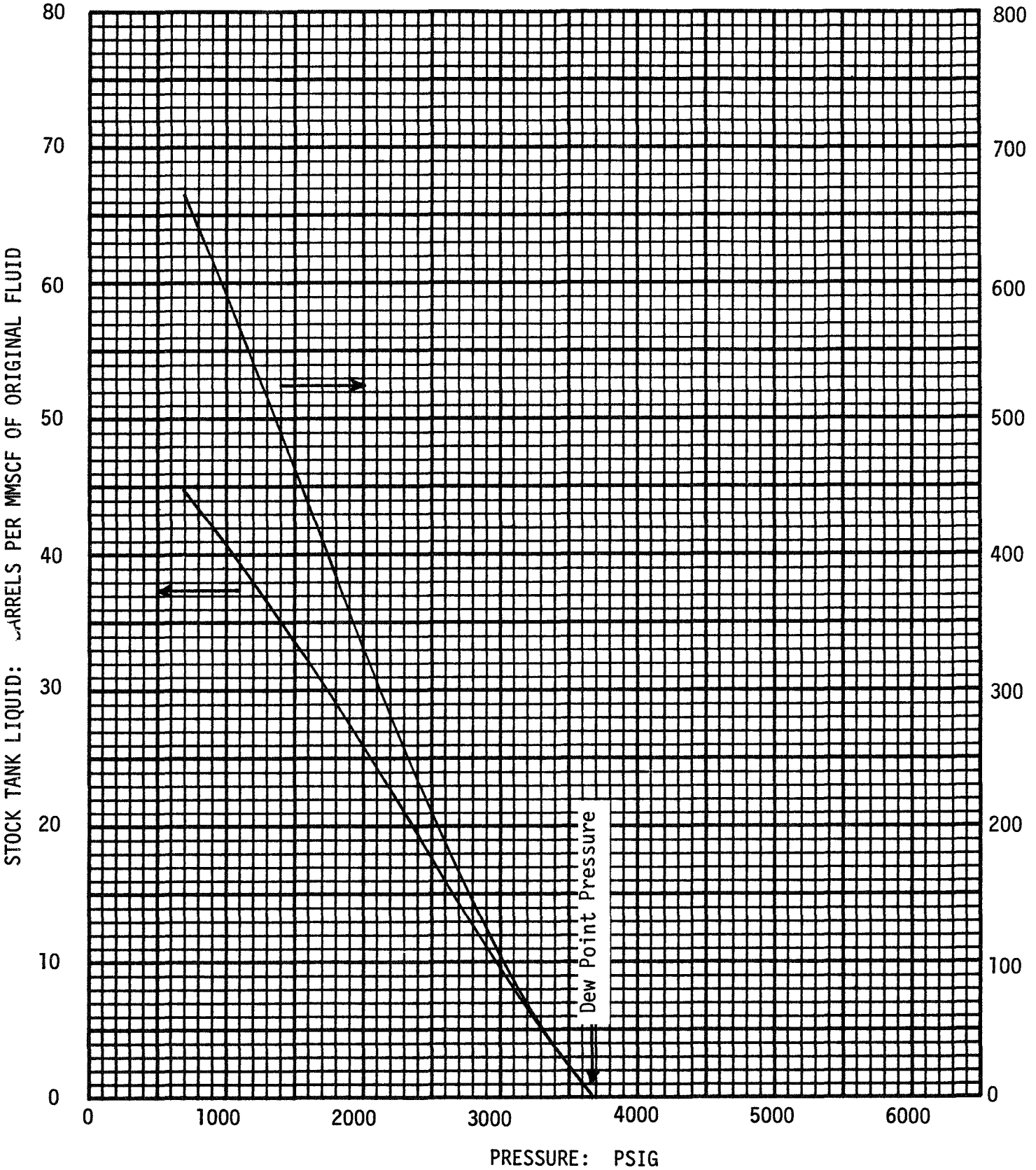
Formation
State
Country NORWAY



# CALCULATED CUMULATIVE RECOVERY DURING DEPLETION

Company STATOIL
Well 15/8-1 DST 1C
Field SLEIPNER

Formation
State
Country NORWAY



# RECOVERY OF PLANT PRODUCTS IN WELL STREAM DURING DEPLETION

Company STATOIL
Well 15/8-1 DST 1C
Field SLEIPNER

Formation
State
Country NORWAY