Reservoir Fluid Study

STATOIL
15/8-1 Well DST 2
Sleipner Field
Norway

RFL 830490

7501 STEMMONS FREEWAY, BOX 47547, DALLAS, TEXAS 75247 · 214/631-8270

September 2, 1983

CORE LABORATORIES, INC.

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 2
Sleipner Field
Norway
RFL 830490

Gentlemen:

Samples of separator gas and liquid collected from the subject well by your representatives on December 16, 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 5544 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 3737 standard cubic feet of primary separator gas per barrel of primary separator liquid at 410 psig and 85°F. The separator products were physically recombined to

the latter ratio, and 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.

A portion of the recombined fluid was charged to a high pressure, windowed cell at reservoir temperature (262°F.). During a constant composition expansion at this temperature, a retrograde dew point was observed at 4227 psig which is significantly below the reported reservoir pressure of 6868 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 18.6 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:bt
10 cc: Addressee

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Howe Moss Road
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Attn: Mr. Les Sebborn

CORE LABORATORIES, INC.

Reservoir Fluid Analysis

File RFL 830490

Company STATOIL | Date Sampled December 16, 1981

Well 15/8-1 DST 2 | 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	6868 PSIG @ Ft.
Date	
Reservoir Temperature	262 °F. @ Ft.
Status of Well	
Pressure Gauge	

SAMPLING CONDITIONS

Flowing Tubing Pressure	3179 PSIG @ 161°F.	
Flowing Bottom Hole Pressure		PSIG
Primary Separator Pressure	410	PSIG
Primary Separator Temperature	90	°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	5544	SCF/Bbl
or	180.38	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.
001-107*	410	90	410	70
001-103	410	90	40	70

Separator Liquid

	Separator Conditions		Laboratory Bubble Point Pressure	
Cylinder Number	Pressure, PSIG	Temperature, °F.	Pressure, PSIG	Temperature, °F.
001-T	410	85	378	71

*Selected for recombination

HYDROCARBON ANALYSIS OF SEPARATOR GAS SAMPLE

Component	Mol Percent	GPM
Hydrogen Sulfide	0.00	
Carbon Dioxide	23.44	
Nitrogen	2.12	
Methane	56.24	
Ethane	7.01	1.874
Propane	7.85	2.160
iso-Butane	1.27	0.415
n-Butane	1.34	0.422
iso-Pentane	0.32	0.117
n-Pentane	0.20	0.072
Hexanes	0.11	0.045
Heptanes	0.06	0.025
Octanes	0.03	0.013
Nonanes	0.01	0.005
Decanes plus	Trace	0.000
	100.00	5.148

Calculated gas gravity (air = 1.000) = 0.952

Calculated gross heating value = 1008 BTU per cubic foot of dry gas at 14.73 psia and 60°F.

Collected at 410 psig and 90°F.

Cylinder: 001-103

Note: Cylinder contained approximately 4 percent air.

HYDROCARBON ANALYSIS OF SEPARATOR GAS SAMPLE

Component	Mol Percent	GPM
Hydrogen Sulfide	0.00	
Carbon Dioxide	23.42	
Nitrogen	2.10	
Methane	56.17	
Ethane	6.98	1.866
Propane	7.88	2.168
iso-Butane	1.30	0.425
n-Butane	1.39	0.438
iso-Pentane	0.34	0.125
n-Pentane	0.22	0.079
Hexanes	0.12	0.049
Heptanes	0.06	0.025
Octanes	0.02	0.009
Nonanes	Trace	0.000
Decanes plus	Trace	0.000
	100.00	5.184

Calculated gas gravity (air = 1.000) = 0.954

Calculated gross heating value = 1011 BTU per cubic foot of dry gas at 14.73 psia and 60°F.

Collected at 410 psig and 90°F.

Cylinder: 001-107

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	7.21	23.42	19.90	
Nitrogen	0.09	2.10	1.66	
Methane	7.24	56.17	45.52	
Ethane	4.57	6.98	6.46	1.727
Propane	15.67	7.88	9.57	2.633
iso-Butane	4.96	1.30	2.10	0.687
n-Butane	8.32	1.39	2.90	0.914
iso-Pentane	4.15	0.34	1.17	0.428
n-Pentane	5.38	0.22	1.34	0.485
Hexanes	7.19	0.12	1.66	0.646
Heptanes	6.12	0.06	1.38	4.692*
Octanes	7.69	0.02	1.69	
Nonanes	5.89	Trace	1.28	
Decanes plus	15.52	Trace	3.37	
	100.00	100.00	100.00	12.212
Properties of Heptanes plus				
API gravity @ 60°F.	39.0			
Density, Gm/Cc @ 60°F.	0.8293		0.828	
Molecular weight	159	103	159	

Calculated separator gas gravity (air=1.000) = 0.954
Calculated gross heating value for separator gas = 1011 BTU per cubic foot of dry gas @ 14.73 psia and 60°F.

Primary separator gas collected @ 410 psig and 90°F.
Primary separator liquid collected @ 410 psig and 85°F.

Primary separator gas/separator liquid ratio = 3737 SCF/Bbl @ 85°F.
Primary separator liquid/stock tank liquid ratio = 1.4835 Bbls @ 85°F./Bbl
Primary separator gas/well stream ratio = 782.67 MSCF/MMSCF
Stock tank liquid/well stream ratio = 141.18 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	1.59	2.98
Benzene	0.00	0.00
Cyclohexane	2.77	5.19
Heptanes	5.85	9.20
Methyl-Cyclohexane	5.51	8.84
Toluene	2.29	3.92
Octanes	6.58	9.08
Ethylbenzene	0.66	0.97
Meta & Para Xylenes	5.73	8.50
Orthoxylene	0.82	1.22
Nonanes	4.91	6.02
iso-Propyl Benzene	0.32	0.42
n-Propyl Benzene	0.67	0.87
1,2,4 Trimethylbenzene	0.94	1.23
Decanes	5.47	6.05
Undecanes	5.09	5.13
Dodecanes	4.04	3.74
Tridecanes	4.82	4.12
Tetradecanes	4.53	3.60
Pentadecanes	4.51	3.34
Hexadecanes	3.17	2.20
Heptadecanes	3.04	1.99
Octadecanes	3.82	2.37
Nonadecanes	2.40	1.41
Eicosanes plus	20.47	7.61
	100.00	100.00

Calculated average molecular weight = 158

PRESSURE-VOLUME RELATIONS OF RESERVOIR FLUID AT 262°F.
(Constant Composition Expansion)

Pressure, PSIG		Relative Volume	Deviation Factor, Z
6868	Reservoir Pressure	0.8482	1.218(1)
6500		0.8599	1.169
6000		0.8811	1.106
5500		0.9057	1.042
5000		0.9357	0.980
4700		0.9572	0.942
4500		0.9733	0.917
4400		0.9824	0.905
4300		0.9919	0.893
4227	Dew Point	1.0000	0.885(2)
4150		1.0088	
4050		1.0211	
3900		1.0416	
3700		1.0748	
3400		1.1352	
3100		1.2136	
2800		1.3180	
2500		1.4600	
2305		1.5803	
2000		1.8213	
1700		2.1650	
1421		2.6369	
1199		3.1666	

(1) Gas expansion factor = 1.551 MSCF/Bbl
(2) Gas expansion factor = 1.316 MSCF/Bbl

DEPLETION STUDY AT 262°F.

Hydrocarbon Analyses of Produced Well Stream - Mol Percent

	Reservoir Pressure - PSIG							
Component	4227	3700	3000	2300	1700	1200	700	700*
Hydrogen Sulfide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbon Dioxide	19.95	19.96	20.20	21.26	21.49	21.70	22.10	5.35
Nitrogen	1.80	1.89	1.97	2.08	2.08	1.98	1.81	0.15
Methane	45.41	47.72	49.68	50.01	50.26	49.76	47.70	6.98
Ethane	6.36	6.38	6.40	6.57	6.66	6.82	6.96	2.93
Propane	9.56	9.37	9.22	9.21	9.38	9.73	10.45	8.29
iso-Butane	2.12	1.97	1.96	1.90	1.94	2.11	2.26	2.82
n-Butane	2.93	2.74	2.70	2.60	2.63	2.75	3.02	4.60
iso-Pentane	1.18	1.12	1.08	1.03	1.02	1.02	1.05	2.51
n-Pentane	1.34	1.22	1.18	1.14	1.12	1.12	1.16	3.26
Hexanes	1.63	1.55	1.40	1.25	1.15	1.10	1.20	5.62
Heptanes plus	7.72	6.08	4.21	2.95	2.27	1.91	2.29	57.49
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Molecular weight of heptanes plus	159	132	123	116	112	108	105	175
Density of heptanes plus	0.828	0.802	0.793	0.785	0.782	0.776	0.774	0.838
Equilibrium gas	0.885	0.824	0.795	0.808	0.835	0.875	0.921	
Two-phase	0.885	0.831	0.785	0.754	0.742	0.723	0.674	
Well Stream produced-								
Cumulative percent of initial	0.000	6.921	19.669	36.061	51.865	64.995	77.940	

*Composition of 700 psig equilibrium liquid phase.

CALCULATED CUMULATIVE RECOVERY DURING DEPLETION

Cumulative Recovery per MMSCF of Original Fluid	Initial in Place	Reservoir Pressure - PSIG 4227	3700	3000	2300	1700	1200	700
Well Stream - MSCF	1000	0	69.21	196.69	360.61	518.65	649.95	779.40
Normal Temperature Separation								
Stock Tank Liquid - Barrels	153.25	0	7.75	17.96	27.55	35.02	40.46	46.64
Primary Separator Gas-MSCF	784.09	0	56.86	166.63	312.63	455.80	575.45	691.08
Stock Tank Gas - MSCF	88.02	0	5.09	12.72	20.81	27.84	33.67	40.83
Total "Plant Products" in Primary Separator Gas-Gallons								
Ethane	1447	0	104	302	569	832	1058	1282
Propane	1714	0	125	372	707	1046	1342	1644
Butanes (total)	656	0	48	151	293	442	577	711
Pentanes plus	269	0	21	65	129	195	252	303
Total "Plant Products" in Stock Tank Gas - Gallons								
Ethane	238	0	13	33	52	69	82	99
Propane	730	0	42	105	171	228	276	336
Butanes (total)	501	0	29	77	130	178	221	275
Pentanes plus	223	0	14	38	66	93	117	144
Total "Plant Products" in Well Stream - Gallons								
Ethane	1700	0	118	336	624	906	1145	1386
Propane	2616	0	178	502	917	1325	1676	2048
Butanes (total)	1616	0	104	294	531	762	966	1185
Pentanes plus	6274	0	322	763	1202	1562	1834	2128

Primary separator at 410 psig and 90°F.; stock tank at 50°F.

CALCULATED INSTANTANEOUS RECOVERY DURING DEPLETION

	Reservoir Pressure - PSIG						
	4227	3700	3000	2300	1700	1200	700
Normal Temperature Separation							
Stock Tank Liquid Gravity, °API at 60°F.	52.7	59.9	64.2	67.8	70.2	72.6	72.7
Separator Gas/Well Stream Ratio, MSCF/MMSCF							
Primary Separator Gas Only	784.09	821.59	861.05	890.66	905.95	911.26	892.94
Primary Stage Separator and Stock Tank Gases	872.11	895.13	920.94	939.98	950.41	955.66	948.28
Separator Gas/Stock Tank Liquid Ratio, SCF/STB							
Primary Separator Gas Only	5116	7341	10750	15215	19182	22001	18692
Primary Stage Separator and Stock Tank Gases	691	7998	11497	16058	20123	23073	19851
GPM from Smooth Well Stream Compositions							
Ethane plus	12.207	10.442	9.199	8.410	8.101	8.125	8.703
Propane plus	10.506	8.736	7.488	6.653	6.320	6.302	6.842
Butanes plus	7.890	6.158	4.952	4.120	3.740	3.625	3.968
Pentanes plus	6.274	4.651	3.460	2.679	2.277	2.069	2.277

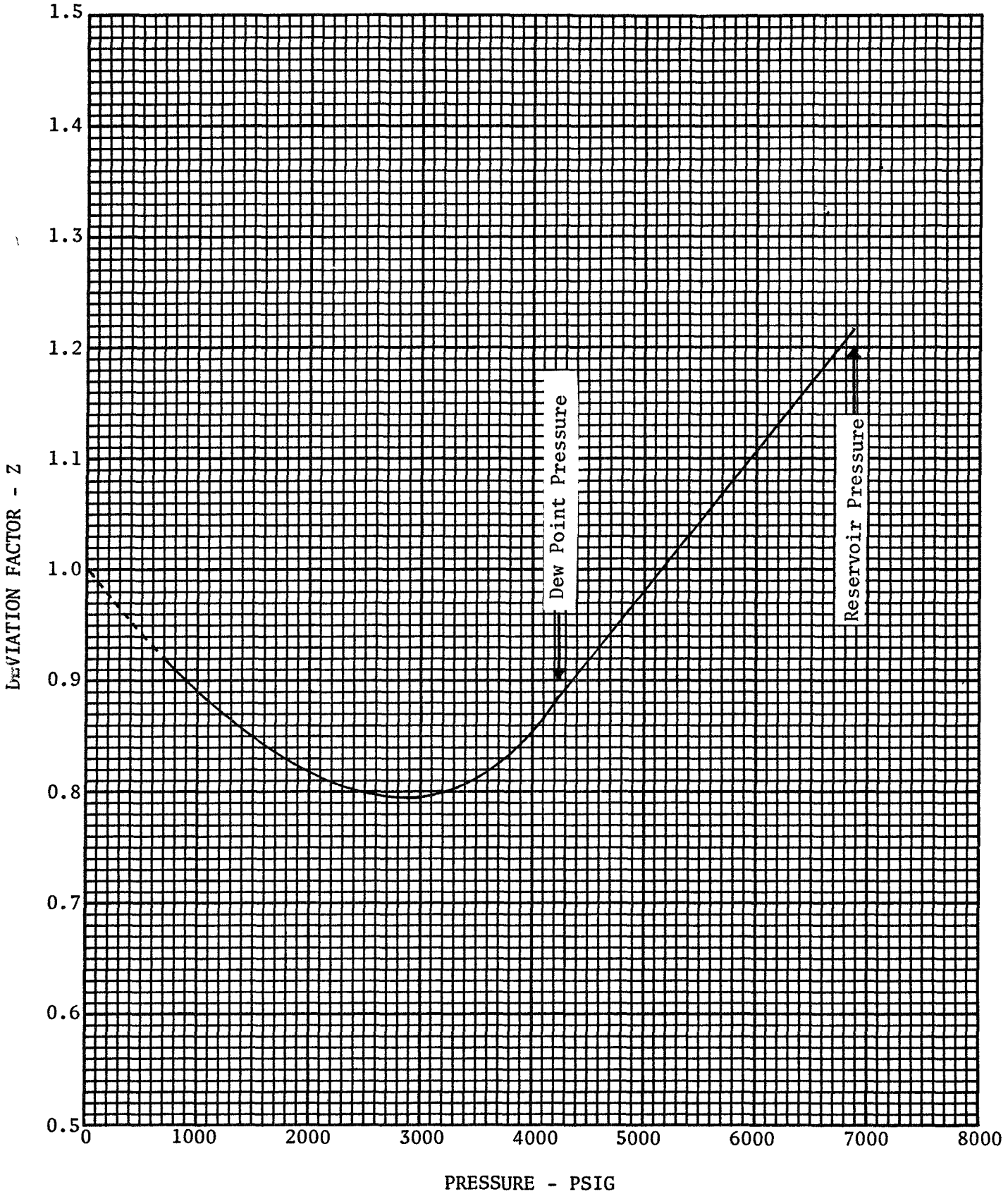
RETROGRADE CONDENSATION DURING GAS DEPLETION AT 262°F.

Pressure, PSIG		Retrograde Liquid Volume, Percent of Hydrocarbon Pore Space
4227	Dew Point	0.0
4150		0.2
4050		0.5
3900		3.2
3700	First Depletion Pressure	8.9
3000		16.6
2300		18.6
1700		18.0
1200		16.9
700		15.5
0		10.0

DEVIATION FACTOR OF GAS PHASE DURING DEPLETION

Company STATOIL
Well 15/8-1 DST 2
Field SLEIPNER

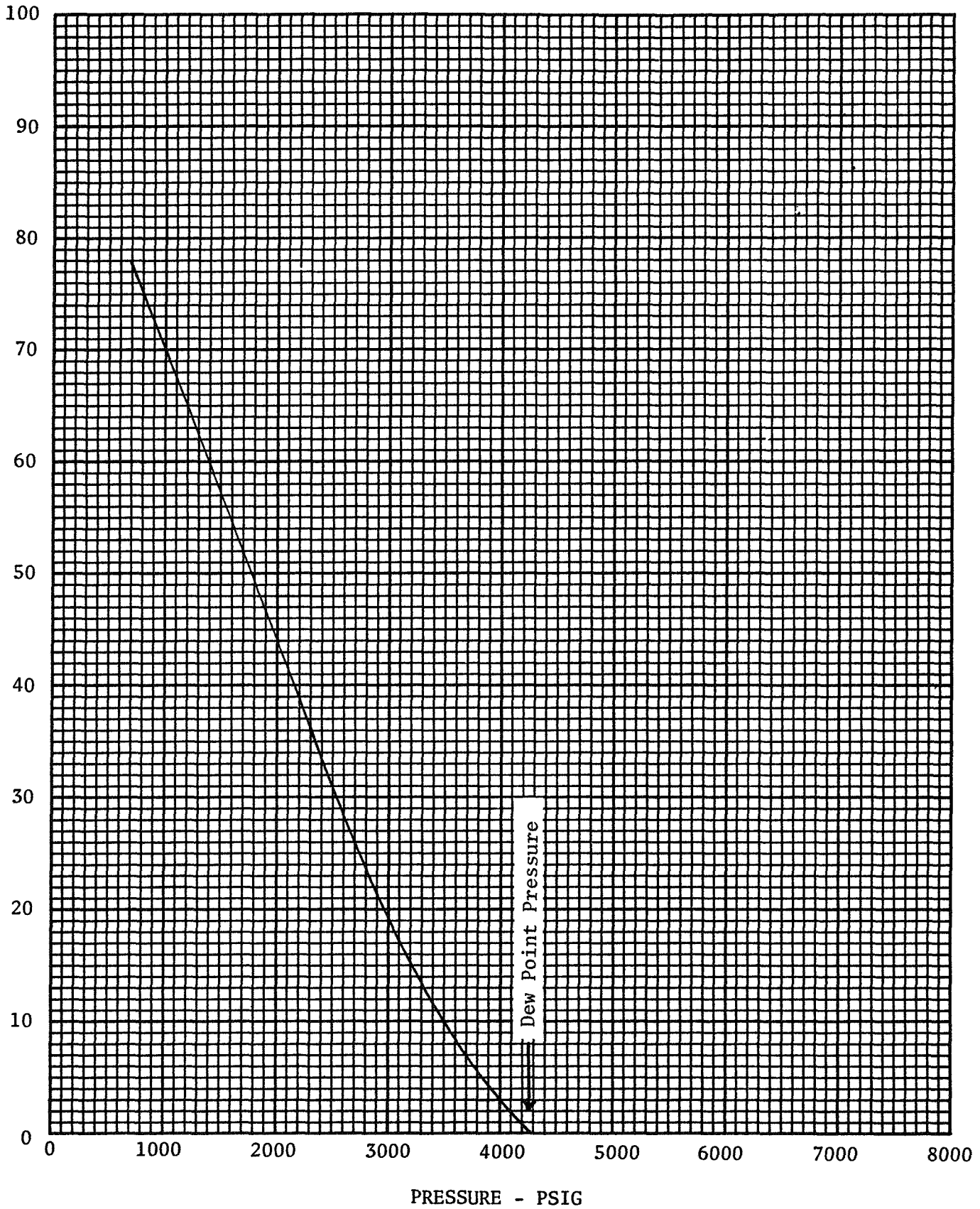
Formation
State
Country NORWAY



CUMULATIVE PRODUCED VOLUME DURING DEPLETION

Company STATOIL
Well 15/8-1 DST 2
Field SLEIPNER

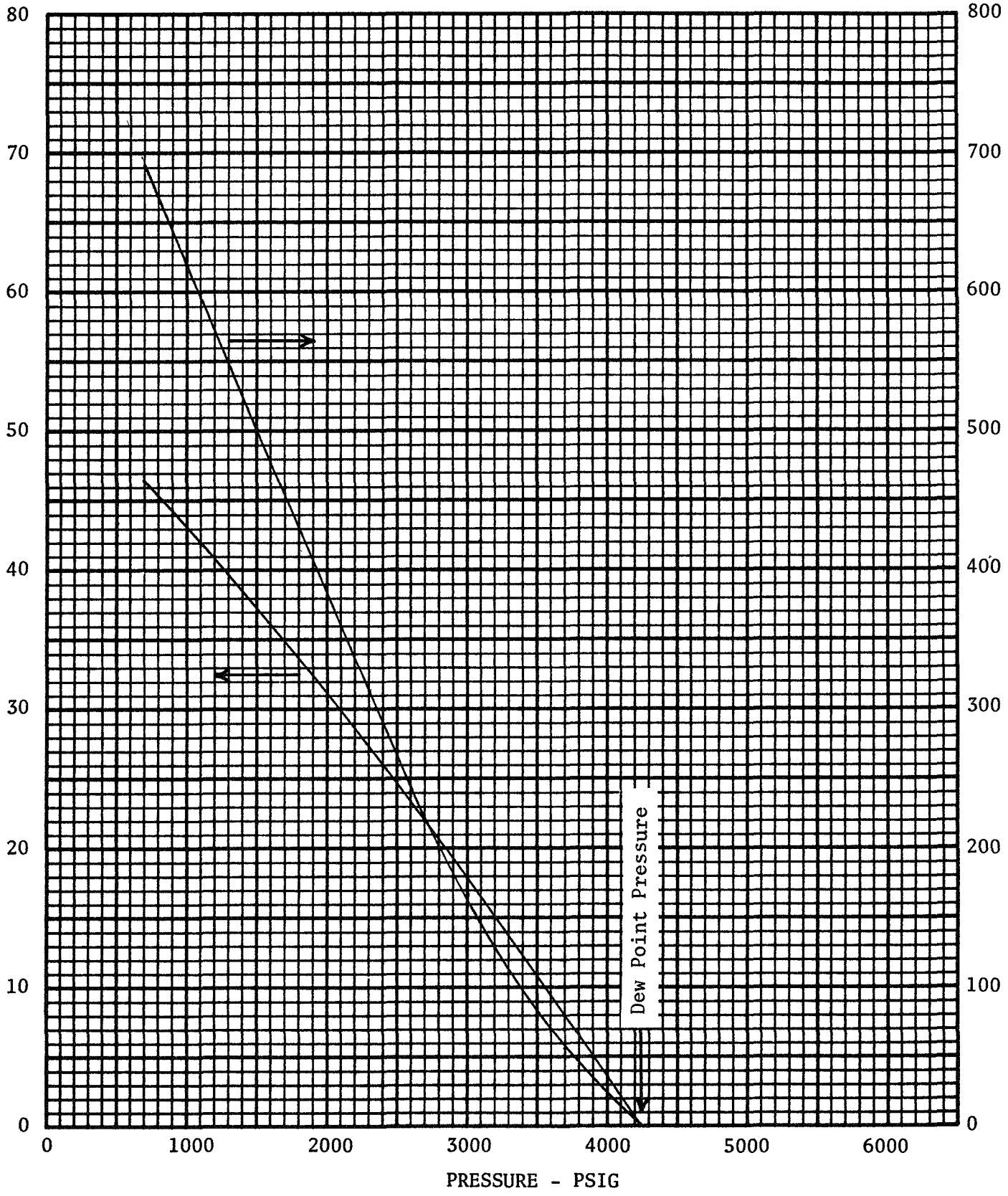
Formation
State
Country NORWAY



CALCULATED CUMULATIVE RECOVERY DURING DEPLETION

Company STATOIL
Well 15/8-1 DST 2
Field SLEIPNER

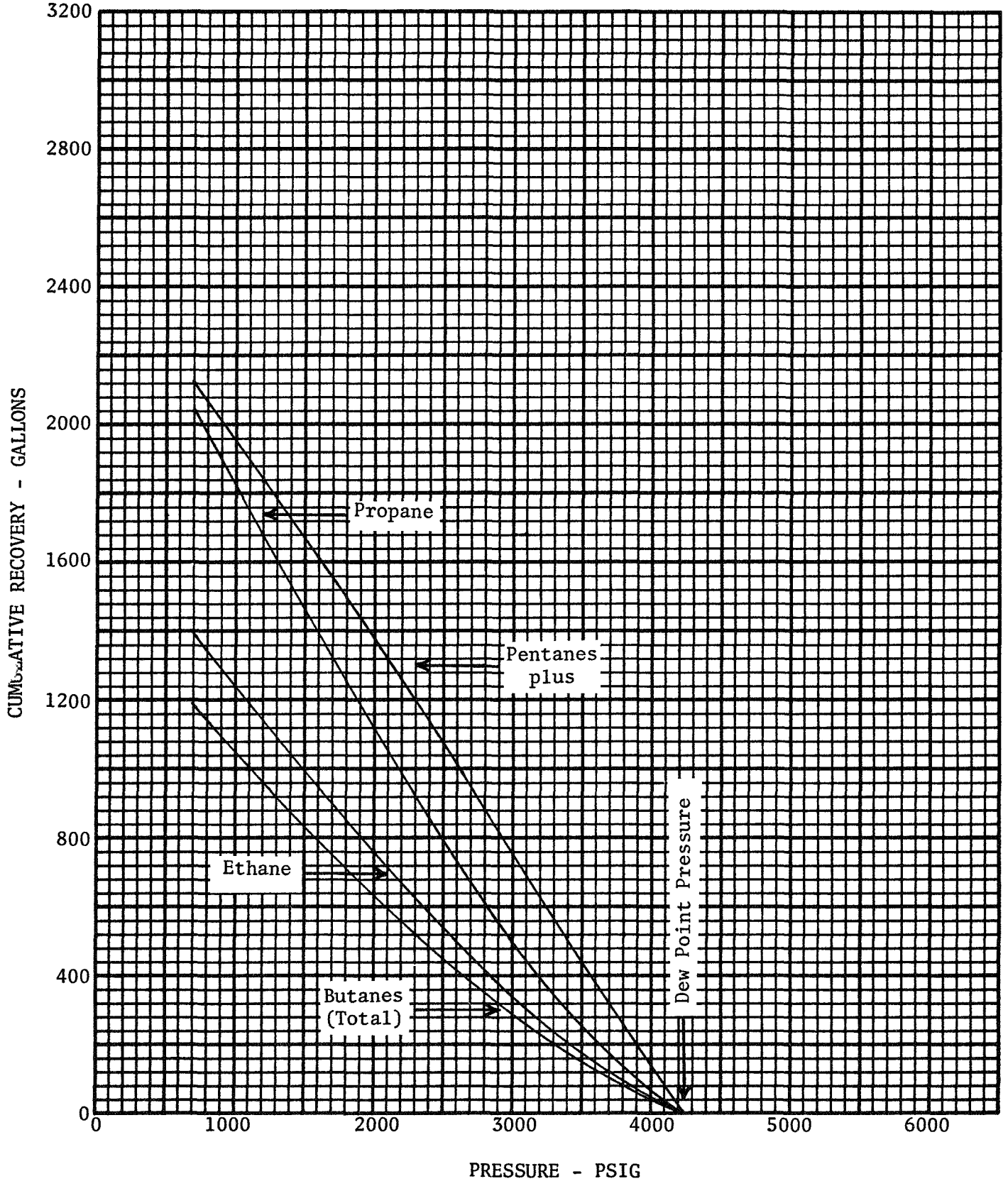
Formation
State
Country NORWAY



RECOVERY OF PLANT PRODUCTS IN WELL STREAM DURING DEPLETION

Company STATOIL
Well 15/8-1 DST 2
Field SLEIPNER

Formation
State
Country NORWAY



RETROGRADE CONDENSATION DURING DEPLETION

Company STATOIL
Well 15/8-1 DST 2
Field SLEIPNER

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State
Country NORWAY