Reservoir Fluid Study

DIAMOND SHAMROCK CORPORATION
Ackerman State 41-16 Well
Wildcat
Converse County, Wyoming

RFL 80925

File

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

April 3, 1981

CORE LABORATORIES, INC.

P. L. Moses
Manager
Reservoir Fluid Analysis

Diamond Shamrock Corporation
Suite 600
410 17th Street
Denver, CO 80202

Attention: Mr. John Richardson

Subject: Reservoir Fluid Study
Ackerman State 41-16 Well
Wildcat
Converse County, Wyoming
RFL 80925

Gentlemen:

Samples of first stage separator gas and liquid were collected from the subject well by Core Laboratories, Inc. personnel on December 4, 1980. A reservoir fluid study has been performed in our laboratory in Dallas using these samples, and the results of the study are presented in this report.

At the time of sampling, the well was producing at a stable gas-liquid ratio of 1745 standard cubic feet of first stage separator gas per barrel of stock tank liquid. In the laboratory, this was experimentally determined to be equivalent to 1667 standard cubic feet of gas per barrel of separator liquid at the separator conditions. The separator products were physically recombined in these proportions, and the resulting mixture was used in the entire study.

The separator liquid composition was measured by low temperature fractional distillation and the separator gas composition was measured by routine chromatography. The analysis of the separator liquid was extended to undecanes plus by analyzing the heptanes plus fraction with a high temperature chromatograph. The well stream composition was calculated from the gas and liquid compositions on the basis of the producing gas-liquid ratio.

The recombined fluid sample was charged to a visual cell at the reservoir temperature of 248°F. The bubble point pressure of the fluid was 3840 psig at this temperature. The pressure-volume relations of the fluid were measured over a wide range of pressures up to 8000 psig. During this test, the liquid shrinkage was very high immediately below the bubble point pressure, indicating that the fluid was fairly volatile. This information was discussed with you, and it was decided that a volatile oil depletion study should be performed.

A large sample of the recombined fluid was charged to a high pressure cell and the volume at the bubble point was measured. The fluid was then subjected to constant-volume depletion at the reservoir temperature. This depletion consisted of a series of expansions and constant-pressure displacements of the equilibrium gas phase. Each displacement was terminated when the total sample volume equaled the original volume at the bubble point. The gases displaced from the cell were charged directly to low temperature fractional distillation equipment, and the gas compositions and volumes were measured. The condensable liquid contents of the gases were then calculated from the gas compositions, and the cumulative "plant products" in the well stream were calculated.

The liquid phase volume was measured visually at each depletion level. At atmospheric pressure, the volume of the liquid phase in the cell was 40.8 percent of the original saturated volume.

The viscosity of the liquid phase was measured during a similar depletion. The viscosity increased from 0.126 centipoise at the bubble point to 0.896 centipoise at one atmosphere. The gas phase viscosities were calculated from the compositions using the Carr, Kobayashi, and Burrows correlation.

Three separator tests were performed at specified separator pressures and temperatures. First stage separator gas from one test and first and second stage gases from a multi-stage test were collected and analyzed.

It was a pleasure to perform this study for you and we hope we may be of further service in the near future. Please do not hesitate to call on us if you have any questions or comments concerning the data.

Very truly yours,

CORE LABORATORIES, INC.

James R. Fortner

James R. Fortner
Assistant Manager
Reservoir Fluid Analysis

JRF:JB:bt
7 cc: Addressee

CORE LABORATORIES, INC.
Reservoir Fluid Analysis

File RFL 80925

Company Diamond Shamrock Corporation Date Sampled December 4, 1980

Well Ackerman State 41-16 County Converse

Field Wildcat State Wyoming

FORMATION CHARACTERISTICS

Formation Name	First Frontier
Date First Well Completed	November 1, 1980
Original Reservoir Pressure	7934 PSIG @ 12500 Ft.
Original Produced Gas-Liquid Ratio	1709 SCF/Bbl
Production Rate	179 Bbls/Day
Separator Pressure and Temperature	44 PSIG °F.
Liquid Gravity at 60°F.	45 °API
Datum	Ft. Subsea

WELL CHARACTERISTICS

Elevation	5317 KB Ft.
Total Depth	13230 Ft.
Producing Interval	12744-12852 Ft.
Tubing Size and Depth	2-7/8 In. to 12311 Ft.
Open Flow Potential	MMSCF/Day
Last Reservoir Pressure	PSIG @ Ft.
Date	, 19
Reservoir Temperature	240* °F. @ 12250 Ft.
Status of Well	
Pressure Gauge	

SAMPLING CONDITIONS

Flowing Tubing Pressure		200 PSIG
Flowing Bottom Hole Pressure		PSIG
Primary Separator Pressure		68 PSIG
Primary Separator Temperature		55 °F.
Secondary Separator Pressure		41 PSIG
Secondary Separator Temperature		110 °F.
Field Stock Tank Liquid Gravity		°API @ 60°F.
Primary Separator Gas Production Rate		MSCF/Day
Pressure Base	15.025 PSIA	
Temperature Base	60 °F.	
Compressibility Factor (F_{pv})	1.0000	
Gas Gravity (Laboratory)	0.828	
Gas Gravity Factor (F_g)	0.8513	
Stock Tank Liquid Production Rate @ 60°F.		110 Bbls/Day
Primary Separator Gas/Stock Tank Liquid Ratio		1745 SCF/Bbl
or		Bbls/MMSCF
Sampled by		Core Laboratories, Inc.

REMARKS:
*Temperature extrapolated to 248°F. at 12798 ft. (mpp)

HYDROCARBON ANALYSES OF SEPARATOR PRODUCTS AND CALCULATED WELL STREAM

Component	Separator Liquid, Mol Percent	Separator Gas Mol Percent	Separator Gas GPM	Well Stream, Mol Percent
Hydrogen Sulfide	0.00	0.00		0.00
Carbon Dioxide	0.13	1.58		1.15
Nitrogen	0.01	0.64		0.45
Methane	1.90	67.09		47.81
Ethane	3.30	15.61	4.256	11.97
Propane	7.58	9.95	2.792	9.25
iso-Butane	2.14	1.25	0.417	1.51
n-Butane	6.11	2.45	0.788	3.53
iso-Pentane	3.09	0.57	0.213	1.32
n-Pentane	3.29	0.45	0.166	1.29
Hexanes	6.82	0.22	0.092	2.17
Heptanes plus	65.63	0.19	0.088	19.55
	100.00	100.00	8.812	100.00

Properties of Heptanes plus				
API gravity @ 60°F.	38.7			
Density, Gm/Cc @ 60°F.	0.8311			0.831
Molecular weight	193	102		193

Calculated separator gas gravity (air=1.000) = 0.828

Calculated gross heating value for separator gas = 1417 BTU per cubic foot of dry gas @ 15.025 psia and 60°F.

Primary separator gas collected @ 68 psig and 55 °F.

Primary separator liquid collected @ 68 psig and 55 °F.

Primary separator gas/separator liquid ratio	1667	SCF/Bbl @ 55°F.
Primary separator liquid/stock tank liquid ratio	1.047	Bbls @ 55°F./Bbl
Primary separator gas/well stream ratio	704.20	MSCF/MMSCF

HYDROCARBON ANALYSIS OF HEPTANES PLUS FRACTION OF SEPARATOR LIQUID

Component	Mol Percent	Weight Percent
Methylcyclopentane	0.16	0.07
Benzene	0.02	0.01
Cyclohexane	2.71	1.22
Heptanes	8.63	4.63
Methylcyclohexane	7.00	3.67
Toluene	1.26	0.63
Octanes	10.58	6.46
Ethylbenzene	0.57	0.32
Meta & Para Xylenes	2.40	1.36
Orthoxylene	0.72	0.41
Nonanes	7.91	5.43
1,2,4 Trimethylbenzene	1.70	1.09
Decanes	7.09	5.40
Undecanes plus	49.25	69.30
	100.00	100.00

VOLUMETRIC DATA OF RESERVOIR FLUID SAMPLE

1. Saturation pressure (bubble-point pressure) 3840 PSIG @ 248 °F.
2. Specific volume at saturation pressure: ft ^{3}/lb 0.03112 @ 248 °F.
3. Thermal expansion of saturated oil @ 5000 PSIG = $\frac{V \text{ @ } 248\ ^\circ F.}{V \text{ @ } 73\ ^\circ F.}$ = 1.17122
4. Compressibility of saturated oil @ reservoir temperature: Vol/Vol/PSI:

   From 8000 PSIG to 7000 PSIG = 16.74×10^{-6}

   From 7000 PSIG to 6000 PSIG = 20.14×10^{-6}

   From 6000 PSIG to 5000 PSIG = 25.06×10^{-6}

   From 5000 PSIG to 3840 PSIG = 34.44×10^{-6}

PRESSURE-VOLUME RELATIONS AT 248°F.

Pressure, PSIG	Relative Volume(1)	Density, Gm/Cc
8000	0.9018	0.5711
7500	0.9091	0.5665
7000	0.9171	0.5616
6500	0.9262	0.5560
6000	0.9360	0.5502
5500	0.9477	0.5434
5000	0.9600	0.5365
4500	0.9752	0.5281
4000	0.9931	0.5186
3840	1.0000	0.5150
3820	1.0021	
3800	1.0041	
3755	1.0089	
3660	1.0196	
3500	1.0398	
3000	1.1238	
2500	1.2587	
2000	1.4935	
1500	1.9258	
1280	2.2293	
900	3.1774	
700	4.0700	
645	4.4873	

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

DEPLETION STUDY AT 248°F.

Hydrocarbon Analyses of Produced Gas Phase - Mol Percent

	Reservoir Pressure - PSIG						
Component	3840*	3300	2600	1900	1200	700	700**
Hydrogen Sulfide	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbon Dioxide	1.15	1.40	1.43	1.48	1.51	1.57	0.41
Nitrogen	0.45	0.76	0.73	0.69	0.62	0.53	0.04
Methane	47.81	65.17	67.70	68.49	66.73	61.80	9.47
Ethane	11.97	12.64	12.85	13.30	14.36	16.13	6.98
Propane	9.25	8.52	8.30	8.36	9.20	10.92	9.03
iso-Butane	1.51	1.33	1.24	1.23	1.32	1.59	1.80
n-Butane	3.53	2.64	2.45	2.38	2.59	3.16	5.30
iso-Pentane	1.32	0.92	0.76	0.67	0.70	0.87	2.50
n-Pentane	1.29	0.88	0.72	0.63	0.66	0.83	2.49
Hexanes	2.17	1.18	0.87	0.69	0.63	0.74	5.19
Heptanes plus	19.55	4.56	2.95	2.08	1.68	1.86	56.79
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Molecular weight of heptanes plus	193	119	114	109	106	106	200
Density of heptanes plus	0.831	0.770	0.765	0.760	0.757	0.757	0.838
Deviation Factor - Z							
Equilibrium gas		0.840	0.829	0.846	0.887	0.925	
Gas Phase produced-							
Cumulative percent of initial	0.000	6.494	17.784	31.680	47.305	59.417	
GPM							
Ethane plus		10.570	9.369	8.884	9.300	10.792	
Propane plus		7.123	5.865	5.257	5.384	6.394	
Butanes plus		4.732	3.535	2.911	2.802	3.329	
Pentanes plus		3.440	2.334	1.736	1.529	1.783	

*Reservoir Fluid

**Equilibrium liquid phase

CALCULATED CUMULATIVE RECOVERY DURING DEPLETION
(Per MMSCF of Original Fluid)

Pressure, PSIG	Gas Phase, MSCF	Plant Products in Gas Phase, Gallons			
		Ethane	Propane	Butanes	Pentanes plus
3840	0.00	0	0	0	0
3300	64.94	224	155	84	223
2600	177.84	619	418	220	487
1900	316.80	1123	744	383	728
1200	473.05	1735	1148	582	967
700	594.17	2268	1519	769	1183

VOLUME OF LIQUID PHASE AT 248°F.

Pressure, PSIG		Liquid Phase Volume, Percent of Saturated Volume
3840	Bubble Point	100.0
3800		95.9
3755		92.7
3660		89.0
3500		82.7
3300	First Depletion Level	79.9
2600		71.0
1900		64.0
1200		58.4
700		54.4
0		40.8

VISCOSITY AT 248°F.

Pressure, PSIG	Viscosity, Centipoises Liquid	Gas*	Liquid/Gas Viscosity Ratio
8000	0.198		
7000	0.181		
6000	0.164		
5500	0.157		
5000	0.148		
4500	0.138		
4200	0.133		
3840	0.126		
3600	0.140		
3300	0.157	0.0230	6.83
3000	0.177		
2600	0.208	0.0204	10.19
2200	0.240		
1900	0.271	0.0170	15.94
1600	0.306		
1200	0.364	0.0149	24.43
700	0.460	0.0133	34.59
0	0.896		

*Gas viscosity data calculated from gas gravity and using method of Carr, Kobayashi, and Burrows: Petroleum Transactions AIME, Vol. 201: p. 267 (1954).

SEPARATOR TESTS OF RESERVOIR FLUID SAMPLE

Separator Pressure, PSIG	Temp., °F.	Gas/Oil Ratio (1)	Gas/Oil Ratio (2)	Tank Oil Gravity, °API @ 60°F.	Formation Volume Factor(3)	Separator Volume Factor(4)	Gas Gravity
50 to 0	70	1779	1877			1.055	0.805*
	70	72	73	45.8	2.236	1.005	1.158
			1950				
200 to 0	70	1419	1629			1.148	0.761
	70	237	239	46.7	2.197	1.005	1.339
			1868				
200 to 50	70	1444	1644			1.138	0.756*
	70	72	79			1.099	0.926*
to 0	70	139	139	46.8	2.194	1.006	1.258
			1862				

*Gases collected and analyzed in the laboratory.

(1) Gas/Oil Ratio in cubic feet of gas at 15.025 psia and 60°F. per barrel of oil at indicated pressure and temperature.
(2) Gas/Oil Ratio in cubic feet of gas at 15.025 psia and 60°F. per barrel of stock tank oil at 60°F.
(3) Formation Volume Factor is barrels of saturated oil at 3840 psig and 248°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.

HYDROCARBON ANALYSIS OF FIRST STAGE SEPARATOR GAS SAMPLE

Component	Mol Percent	GPM
Hydrogen Sulfide	0.00	
Carbon Dioxide	1.60	
Nitrogen	0.68	
Methane	68.36	
Ethane	15.68	4.169
Propane	9.66	2.643
iso-Butane	1.12	0.364
n-Butane	2.07	0.649
iso-Pentane	0.41	0.149
n-Pentane	0.32	0.115
Hexanes	0.08	0.033
Heptanes plus	0.02	0.009
	100.00	8.131

Calculated gas gravity (air = 1.000) = 0.805

Calculated gross heating value = 1345 BTU per cubic foot of dry gas at 15.025 psia and 60°F.

Collected at 50 psig and 70°F. from two-stage test.

HYDROCARBON ANALYSIS OF FIRST STAGE GAS SAMPLE

Component	Mol Percent	GPM
Hydrogen Sulfide	0.00	
Carbon Dioxide	1.62	
Nitrogen	0.73	
Methane	73.00	
Ethane	14.73	4.017
Propane	7.39	2.074
iso-Butane	0.72	0.240
n-Butane	1.26	0.405
iso-Pentane	0.22	0.082
n-Pentane	0.17	0.063
Hexanes	0.07	0.029
Heptanes plus	0.09	0.042
	100.00	6.952

Calculated gas gravity (air = 1.000) = 0.756

Calculated gross heating value = 1301 BTU per cubic foot of dry gas at 15.025 psia and 60°F.

Collected at 200 psig and 70°F. from three-stage test.

HYDROCARBON ANALYSIS OF SECOND STAGE SEPARATOR GAS SAMPLE

Component	Mol Percent	GPM
Hydrogen Sulfide	0.00	
Carbon Dioxide	1.90	
Nitrogen	0.68	
Methane	50.15	
Ethane	27.06	7.380
Propane	15.35	4.307
iso-Butane	1.49	0.497
n-Butane	2.46	0.791
iso-Pentane	0.43	0.161
n-Pentane	0.31	0.115
Hexanes	0.13	0.054
Heptanes plus	0.04	0.019
	100.00	13.324

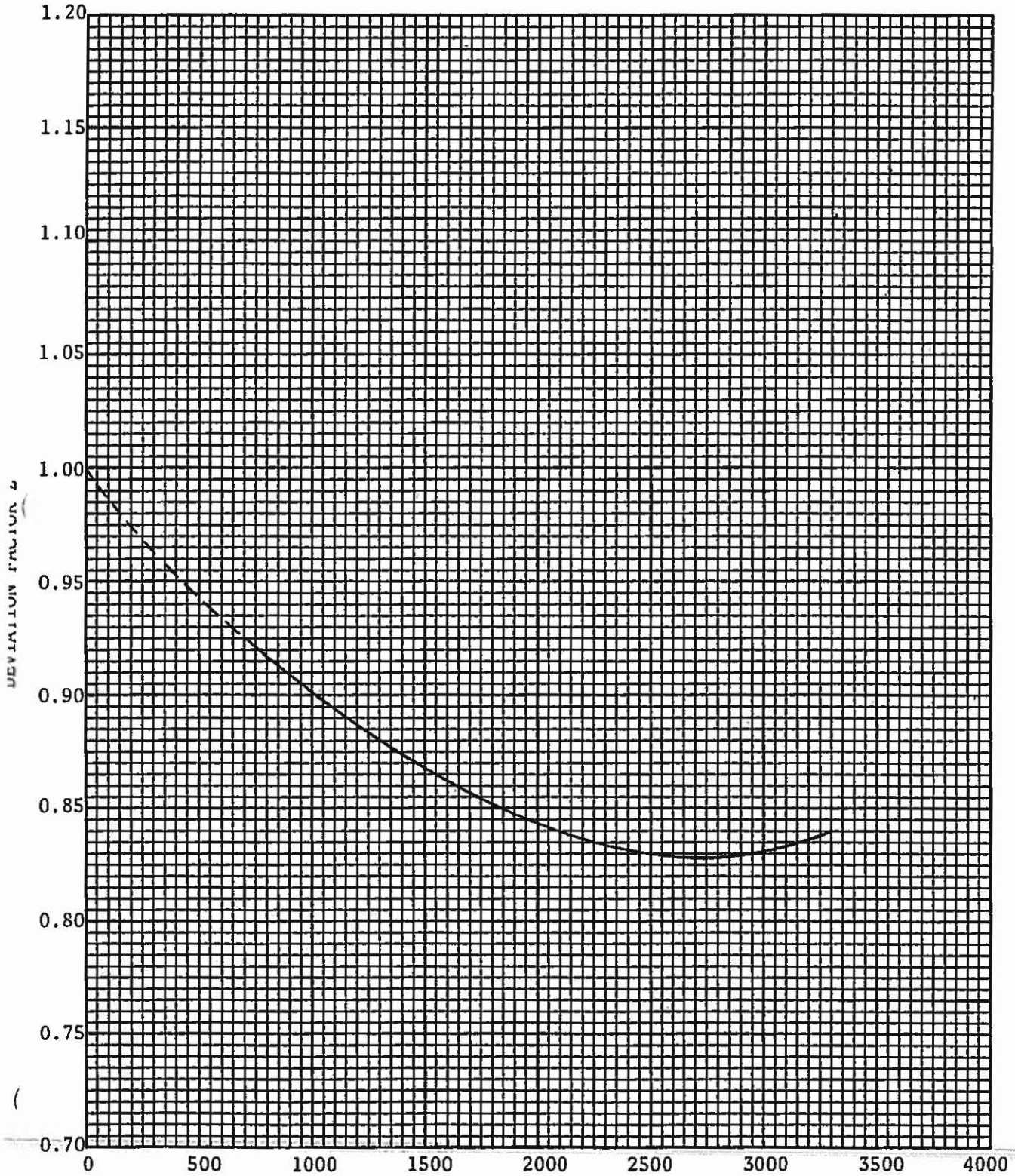
Calculated gas gravity (air = 1.000) = 0.926

Calculated gross heating value = 1574 BTU per cubic foot of dry gas at 15.025 psia and 60°F.

Collected at 50 psig and 70°F. from three-stage test.

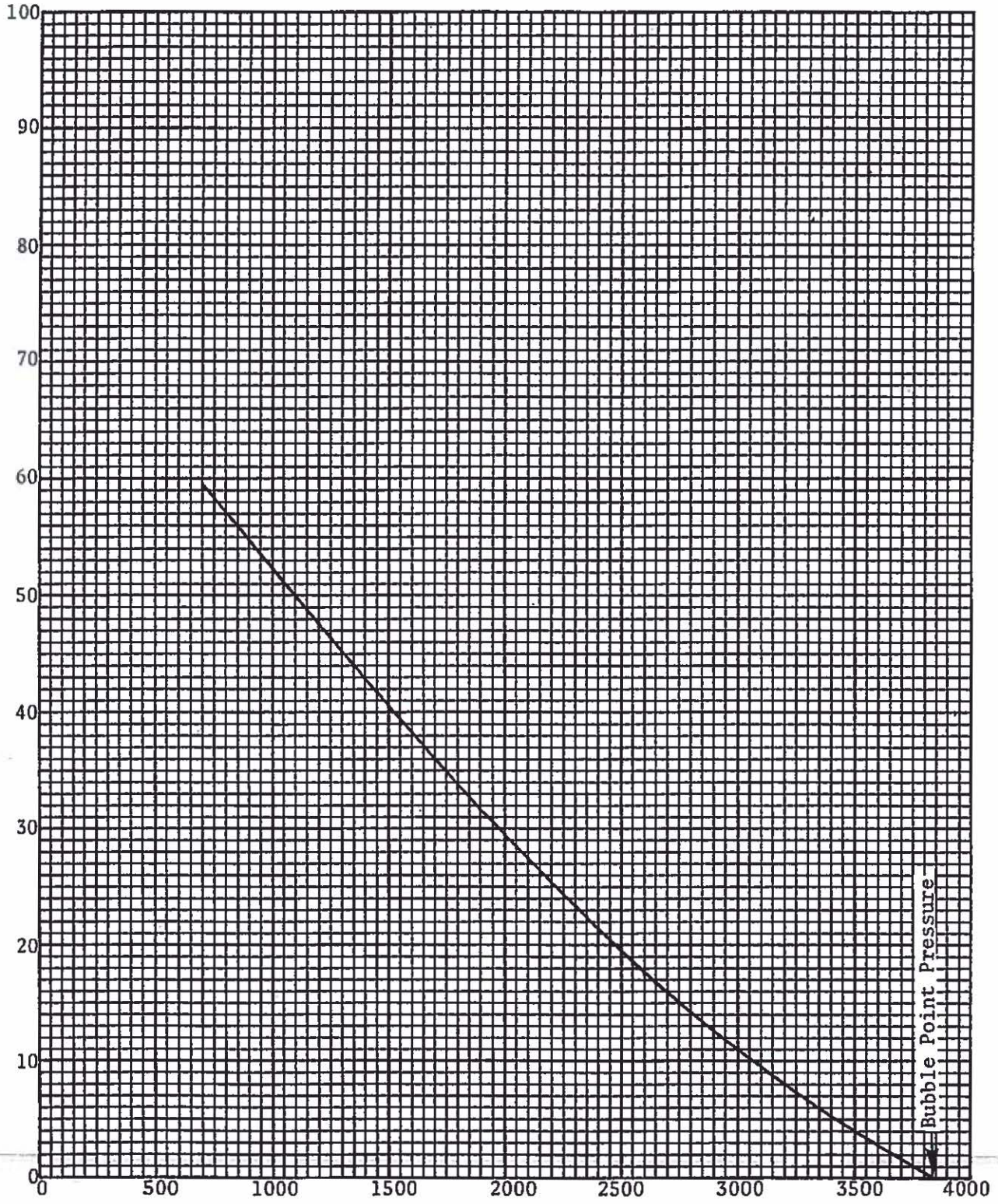
DEVIATION FACTOR Z OF GAS PHASE DURING DEPLETION AT 248°F.

Company DIAMOND SHAMROCK CORPORATION Formation FIRST FRONTIER
Well ACKERMAN STATE 41-16 County CONVERSE
Field WILDCAT State WYOMING



VOLUME OF GAS PHASE PRODUCED DURING DEPLETION AT 248°F.

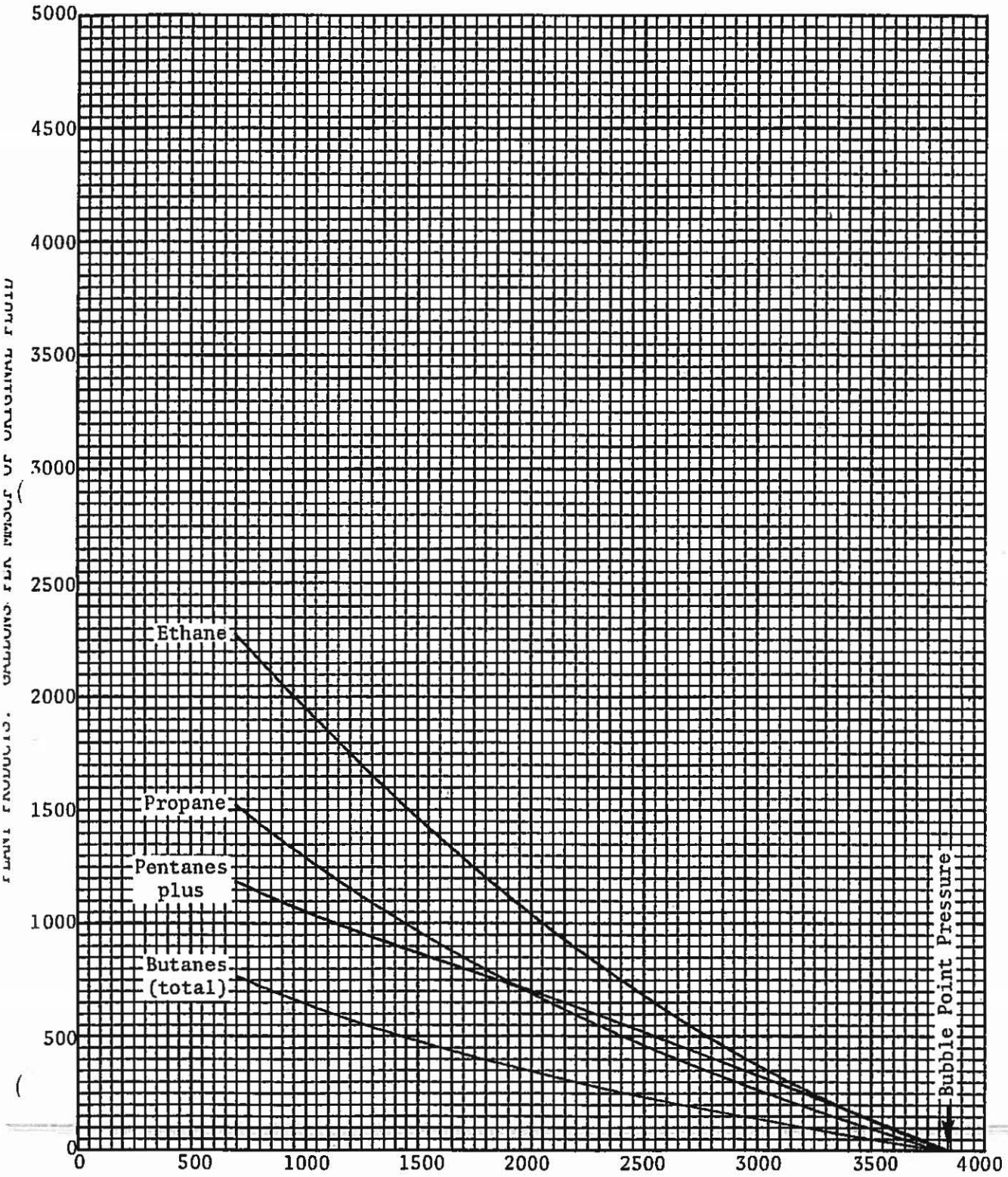
Company DIAMOND SHAMROCK CORPORATION Formation FIRST FRONTIER
Well ACKERMAN STATE 41-16 County CONVERSE
Field WILDCAT State WYOMING



PRESSURE: POUNDS PER SQUARE INCH GAUGE

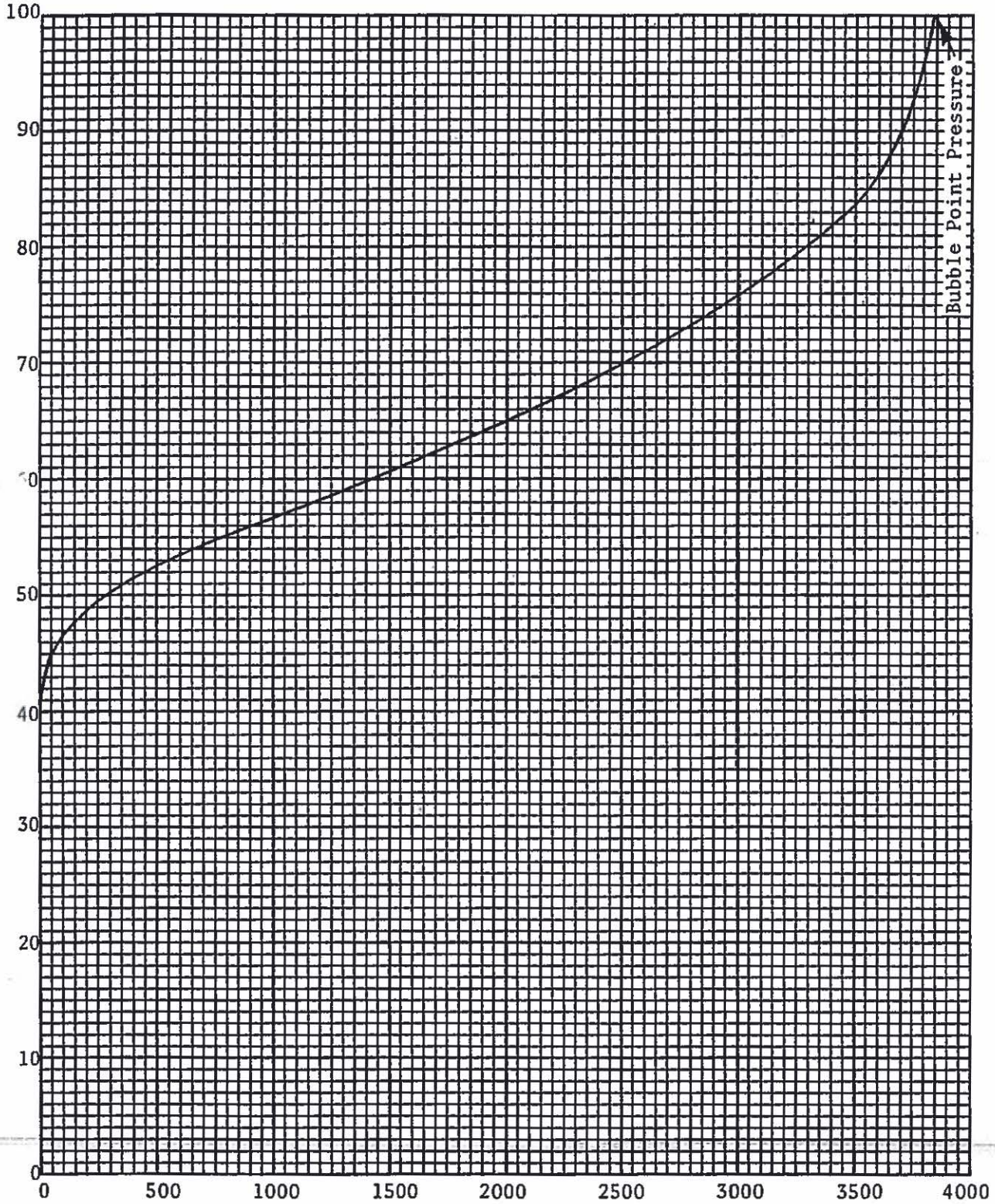
CUMULATIVE RECOVERY - PLANT PRODUCTS IN GAS PHASE

Company DIAMOND SHAMROCK CORPORATION
Well ACKERMAN STATE 41-16
Field WILDCAT
Formation FIRST FRONTIER
County CONVERSE
State WYOMING



VOLUME OF LIQUID PHASE AT 248°F.

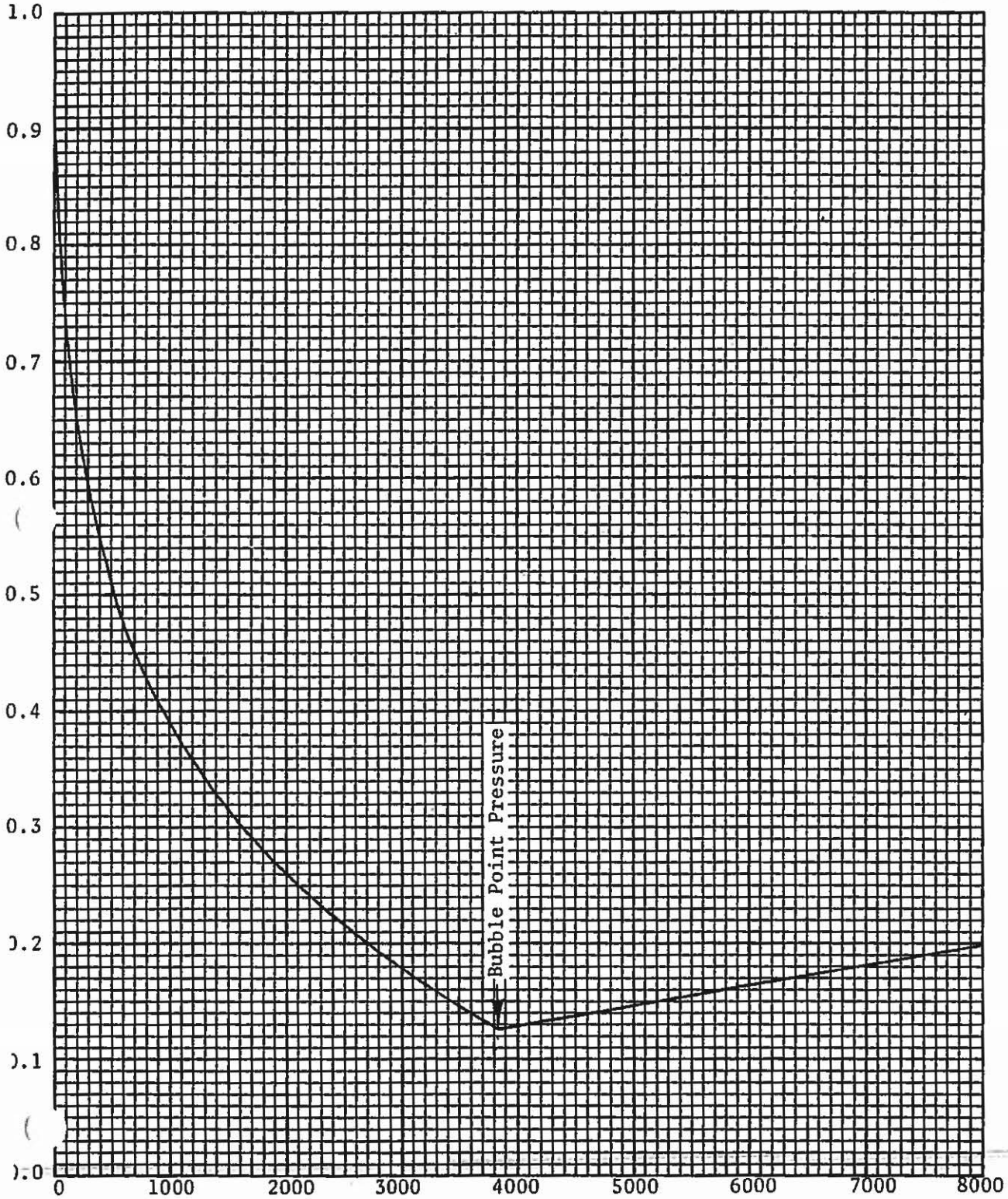
Company DIAMOND SHAMROCK CORPORATION Formation FIRST FRONTIER
Well ACKERMAN STATE 41-16 County CONVERSE
Field WILDCAT State WYOMING



PRESSURE: POUNDS PER SQUARE INCH GAUGE

VISCOSITY AT 248°F.

Company DIAMOND SHAMROCK CORPORATION Formation FIRST FRONTIER
Well ACKERMAN STATE 41-16 County CONVERSE
Field WILDCAT State WYOMING



PRESSURE: POUNDS PER SQUARE INCH GAUGE