Osudo Reservoir Fluid Study
Jordan B No. 1 Well

by

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Reservoir Fluid Study
Jordan "B" No. 1 Well
Osudo Reservoir
Lea County, New Mexico

A reservoir fluid study was performed on first stage separator gas and liquid samples taken from the Jordan "B" No. 1 well. This report contains the following results:

(1) Summary of sampling conditions.

(2) Compositional analysis of the first stage separator gas and first stage separator liquid.

(3) Discussion of field separator scheme and procedure used to calculate the first stage gas oil ratio.

(4) Recombination of separator fluids.

(5) Data obtained from a constant composition expansion (CCE) study of the recombined fluid.

(6) Data obtained from a constant volume depletion (CVD) study of the recombined fluid.

(7) Comparison between Core Laboratory data and PTC data.

Sampling Conditions

Separator gas and liquid samples were obtained from the subject well on June 17, 1992 by a representative of Core Laboratories. Reported field and sampling data are given in Table 1. This data is directly from S. M. Posey, Midland or from the Core Laboratory sampling documentation. Samples were received at PTC on June 25, 1992.

Analysis of Fluid Compositions

The compositions of the separator fluids were analyzed using gas chromatography. The molecular weights of components C_6 - C_{14} are the values reported by Katz and Firoozabadi[1] for general petroleum fractions. The molecular weight of the $C_{15}+$ fraction is calculated using a three step procedure. First, the separator liquid is flashed to atmospheric conditions. Then we measure the molecular weight, specific gravity, and composition of the resulting liquid. The $C_{15}+$ molecular weight is then calculated using the fluid composition and overall molecular weight. The specific gravity for each carbon number fraction is calculated using a constant Watson K factor of 11.920 for each frac-

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[1] Katz, D. L. and Firoozabadi, A., "Predicting Phase Behavior of Condensate/Crude-Oil Systems Using Methane Interaction Coefficients", J. Pet. Tech., November 1978, pp. 1649-1655.

tion. The value of the Watson K factor is picked so that the calculated specific gravity of the stabilized liquid matches the measured value. Table 2 shows the composition of the separator gas. The separator liquid composition is given through C_{15+} in Table 3.

Calculation of First Stage Separator Gas Oil Ratio

Field measurements of the primary separator gas and liquid rates were not available. Instead measurements were obtained for the stock tank oil rate, combined gas rate from the three separators, and gas rate from the stock tank. A schematic diagram of the separator scheme is given in Figure 1. We flashed a sample of separator liquid to the low pressure separator conditions and then flashed the resulting liquid to stock tank conditions. Information obtained from the flash was combined with density and measured fluid compositions to obtain an actual primary gas oil ratio of 9217 scf primary separator gas/bbl primary separator liquid. Table 4 gives a summary of the data used to calculate the actual GOR. In performing these calculaitons, it was assumed that all of the fluid flowed through the 2 stage high pressure separator. S. M. Posey of Midland informed us that approximate 90% of the flow does go through this separator.

Second stage separator liquid was flashed to 12 psia and 90°F. Table 5 gives the properties of the resulting gas and liquid. The GOR reported in Table 5 varies from the field stock tank GOR. The actual field ratio was used in calculating the primary separator flow rates.

Recombination of First Stage Separator Fluids

The separator gas and liquid were recombined with a target GOR of 9217 scf sep gas/bbl sep liquid. The actual GOR of the recombined fluid used by our lab in the phase behavior experiments were 9179 scf sep gas/bbl sep liquid. Table 6 contains the calculated composition of the recombined fluid used in the phase behavior experiments. Molecular weights and specific gravities of the plus fractions and the overall fluid are given in Table 7.

Constant Composition Expansion

The recombined fluid was charged to the PVT cell at reservoir temperature (152°F) and 8428 psia. A constant composition expansion test was performed on the fluid. A visual dew point pressure of 7213 psia was observed. This was the first point at which the fluid remained "cloudy" after equilibration. At 6562 psia we first observed liquid droplets. The first measurable amount of liquid occurred at 5713 psia.

Pressure-Volume relations of the reservoir fluid obtained during the CCE are presented in Table 8. Figures 2 and 3 present the relative volume and compressibility of the fluid as a function of pressure. Figure 4 shows the liquid dropout curve. The liquid volume in this graph is expressed as a percent of the total volume at the current cell pressure. This fluid system exhibits a very long tail on the liquid dropout curve. There is a 1500 psi difference between the visual dew point pressure and the pressure at which we obtained a measurable amount of liquid. We chose to begin the constant volume depletion study at 5713 psia. Thus, the relative volume data in Table 8 are reported relative to the volume at 5713 psia. You can easily recalculate the volumes relative to the total volume at the visual dew point of 7213 psia if necessary. The data presented in Figure 4 are shown as a percent of the total volume at the stated pressure.

Constant Volume Depletion

After completion of the CCE, the fluid was repressurized to 5713 psia. The cell volume was increased until a pressure of 3912 psia was obtained. The fluids were equilibrated and volume measurements were obtained. Then enough gas was removed while maintaining 3912 psia pressure in the cell to return to the original volume at the dew point pressure (5713 psia). This procedure was repeated at 2514, 2012, 1013 and 512 psia. The weight of gas removed was recorded for each depletion step. The composition of the gas obtained at each pressure was measured by gas chromatography. Table 9 gives the measured gas compositions and calculated molecular weights, densities, and compressibility factors. Also stated in Table 9 is the cumulative production as a percent of the initial moles present. Table 10 gives the measured liquid volumes for the depletion steps as percent of the saturation volume. Figure 5 compares the liquid volumes present during the constant composition expansion and the constant volume depletion. The liquid volumes in this figure are expressed as a percent of the saturation volume.

Comparison of PTC Data with Core Laboratory Data

At the start of our reservoir fluid study, there was some concern expressed about the dew point pressure of approximately 5600 psia obtained by Core Laboratories. Several possible sources of error were considered and Core Laboratories took a second set of samples and repeated the compositional analyses of the separator fluids. We obtained samples from the second sampling period. I had several discussions with T. Coleman and F. Vrla of Core Laboratories concerning GOR calculations and fluid compositions. The GOR calculated by Core Laboratories is consistent with the value we obtained from our measurements. The measured liquid composition is also comparable to our measured composition. Core Laboratories reported a dew point pressure of 5600 psia. This value was obtained with the first set of separator samples. This dew point value is consistent with the 5713 psia pressure at which we observed the first measurable amount of liquid. Core Laboratories did not measure the liquid dropout curve so it is impossible to compare the two studies any further.

Table 1
Field Data for Reservoir Fluid Study

Well Record

Well	Jordan "B" No. 1
Field	Osudo
County	Lea
State	New Mexico

Well Characteristics

Formation	Wolfcamp	
Elevation	11,322	ft
Total Depth	11,617	ft
Producing Interval	11,426-11,478	ft
Tubing Size	2 3/8" OD, 1.995" ID	
Tubing Depth	11,314	ft
Reservoir Temperature	153	°F
Reservoir Pressure	3500	psig
Water Cut	19	%
Tubing Pressure (flowing)	1340	psig
Reservoir Pressure (flowing)	3200	psig

Sampling Conditions

Well Testing Company	Core Laboratories	
Date Sampled	6/17/92	
2 stage Primary Separator Temperature	86	°F
2 stage Primary Separator Pressure	490	psig
3 stage Primary Separator Temperature	80	°F
3 stage Primary Separator Pressure	400	psig
Low Pressure Separator Temperature	76	°F
Low Pressure Separator Pressure	150	psig
Gas Meter Temperature	68	°F
Gas Meter Pressure	95	psig
Metered Gas Rate	6022	Mscf/day
(Total of primary and secondary separator gases)		
Stock Tank Temperature	90	°F
Stock Tank Oil Rate	534	STB/day
Stock Tank Water Rate	136	bbl/day
Stock Tank Gas Rate	175	Mscf/day
Standard Pressure	15.025	psia
Standard Temperature	60	°F

Table 2
Separator Gas Composition

Component	Mass Percent	Mole Percent	Molecular Weight
Nitrogen	1.573	1.133	
Carbon Dioxide	0.664	0.304	
Methane	64.422	81.171	
Ethane	15.703	10.517	
Propane	9.438	4.315	
iso-Butane	1.642	0.570	
n-Butane	3.388	1.176	
iso-Pentane	0.943	0.263	
n-Pentane	0.981	0.274	
Hexanes	0.655	0.157	84.00
Heptanes	0.423	0.089	96.00
Octanes	0.160	0.030	107.00
Nonanes	0.008	0.001	121.00
Total	100.00	100.00	

Molecular Weight	20.160
Gas Gravity	0.6959

Table 3
Separator Liquid Composition

Component	Mass Percent	Mole Percent	Molecular Weight	Specific Gravity
Nitrogen	0.00	0.00		
Carbon Dioxide	0.00	0.00		
Methane	2.19	13.35		
Ethane	1.97	6.38		
Propane	3.40	7.50		
iso-Butane	1.41	2.36		
n-Butane	4.02	6.75		
iso-Pentane	2.68	3.61		
n-Pentane	3.56	4.80		
Hexanes	6.31	7.32	84.00	0.7102
Heptanes	10.24	10.39	96.00	0.7293
Octanes	13.05	11.88	107.00	0.7455
Nonanes	8.44	6.79	121.00	0.7614
Decanes	6.80	4.95	134.00	0.7756
Undecanes	5.03	3.33	147.00	0.7880
Dodecanes	4.14	2.51	161.00	0.7998
Tridecanes	4.43	2.47	175.00	0.8102
Tetradecanes	3.33	1.71	190.00	0.8204
C15+	18.99	3.89	475.00	0.8522
Total	100.00	100.00		
C6+	80.77	55.24	142.4	0.7710
C7+	74.45	47.92	151.4	0.7710
C12+	30.89	10.57	284.6	0.8358
C15+	18.99	3.89	475.0	0.8522
Molecular Weight	97.41			
Specific Gravity	0.7016			

Table 4
GOR Determination

Reservoir	Osudo	
Well	Jordan "B" No. 1	
Primary Separator pressure	505	psia
Primary Separator Temperature	86	°F
Pressure Base	15.025	psia
Temperature Base	60	°F
Primary Separator Gas		
Flow Rate (calculated)	5908	Mscf/day
Lab Gas Compressibility Factor (z)	1.1050	
Lab Gas Gravity	0.8598	
Molecular Weight	24.910	g/mol
Density	0.0311	g/cm^3
Density at standard conditions (ideal gas)	0.0671	lb/scf
Secondary Separator Gas		
Lab Gas Compressibility Factor (z)	0.9560	
Flow Rate (measured from two stage flash)	114	Mscf/day
Primary Separator Liquid		
Flow Rate (calculated)	641.0	sep bbl/day
Density	44.88	lb/ft^3
Shrinkage Factor	0.8331	STB/bbl
(S. T. Liquid Volume @ 60 °F/Prim Sep Liq Volume @ 86 °F)		

Gas Oil Ratio using calculated flow rates	9217	scf prim sep gas/bbl prim sep liq
Gas Oil Ratio (g gas/g liquid)	2.453	g gas/g liquid
Gas Oil Ratio of PTC Recombined Fluid	7429	scf prim sep gas/bbl prim sep liq
	1.977	g gas/g liquid

Table 5
Second Stage Separator Liquid
Flashed to 12 psia and 90 °F

Gas Liquid Ratio = 269 scf/STB

Gravity of S.T. Liquid = 64.4 °API @ 60°F

Stock Tank Gas Composition

Component	Mass Percent	Mole Percent	Molecular Weight
Nitrogen	0.000	0.000	
Carbon Dioxide	0.686	0.388	
Methane	40.324	62.778	
Ethane	24.868	20.580	
Propane	18.089	10.217	
iso-Butane	2.976	1.276	
n-Butane	6.175	2.648	
iso-Pentane	1.649	0.569	
n-Pentane	1.712	0.591	
C6+	3.521	0.953	92
Total	100.00	100.00	

Molecular Weight	24.91
Gas Gravity	0.8598

Table 6
Recombined Fluid Composition

Component	Separator Gas Mass Percent	Separator Liquid Mass Percent	Recombined Mass Percent	Recombined Mole Percent
Nitrogen	1.57		1.04	1.03
Carbon Dioxide	0.66		0.44	0.28
Methane	64.42	2.19	43.52	74.75
Ethane	15.70	1.97	11.09	10.13
Propane	9.44	3.40	7.41	4.62
iso-Butane	1.64	1.41	1.56	0.74
n-Butane	3.39	4.02	3.60	1.70
iso-Pentane	0.94	2.68	1.52	0.58
n-Pentane	0.98	3.56	1.85	0.70
Hexanes	0.65	6.31	2.56	0.84
Heptanes	0.42	10.24	3.72	1.06
Octanes	0.16	13.05	4.49	1.15
Nonanes	0.01	8.44	2.84	0.64
Decanes		6.80	2.28	0.47
Undecanes		5.03	1.69	0.32
Dodecanes		4.14	1.39	0.24
Tridecanes		4.43	1.49	0.23
Tetradecanes		3.33	1.12	0.16
C15+		18.99	6.38	0.37
Total	100.00	100.00	100.00	100.00
C6+			27.96	5.49
C7+			25.40	4.65
C12+			10.38	1.00
C15+			6.38	0.37

Table 7
Properties of Recombined Fluid

	Molecular Weight	Specific Gravity
C6+	140.0	0.7802
C7+	150.1	0.7873
C12+	284.6	0.8357
C15+	475.0	0.8522
Total Fluid	27.48	

Table 8
Pressure-Volume Relations at 152°F
Constant Composition Expansion

	Pressure (psia)	Relative Volume(1)	Deviation Factor Z	Liquid Volume Percent(2)
	8428	0.8603	1.0603	
	8212	0.8636	1.0372	
	8020	0.8742	1.0254	
	7813	0.8829	1.0088	
	7612	0.8885	0.9891	
	7414	0.8968	0.9723	
	7213	0.9081	0.9579	Trace
	7012	0.9170	0.9404	Trace
	6812	0.9373	0.9337	Trace
	6562	0.9469	0.9087	Trace
	6464	0.9545	0.9023	Trace
	6362	0.9585	0.8918	Trace
	6212	0.9645	0.8762	Trace
	6012	0.9768	0.8588	Trace
	5813	0.9877	0.8397	Trace
dew point	5713	1.0000	0.8355	0.01
	5613	0.9954	0.8170	0.12
	5512	1.0036	0.8090	0.09
	5412	1.0166	0.8046	0.21
	5313	1.0322	0.8020	0.30
	5212	1.0355	0.7893	0.42
	5011	1.0481	0.7681	0.65
	4813	1.0730	0.7552	1.06
	4613	1.0962	0.7395	1.44
	4362	1.1297	0.7207	1.99
	3912	1.1915	0.6816	3.42
	3415	1.3073	0.6529	5.08
	2912	1.4871	0.6333	7.04
	2513	1.7094	0.6282	7.37
	2012	2.1690	0.6382	6.85
	1512	3.0181	0.6674	4.87
	1262	3.7192	0.6864	3.83

(1) Relative Volume(Bt): V/Vsat is the total volume of fluid(oil and gas) at the indicated pressure per volume of saturated oil at the dew point pressure.

(2) Liquid Volume Percent is calculated as a percent of total volume at 152 °F and the indicated pressure.

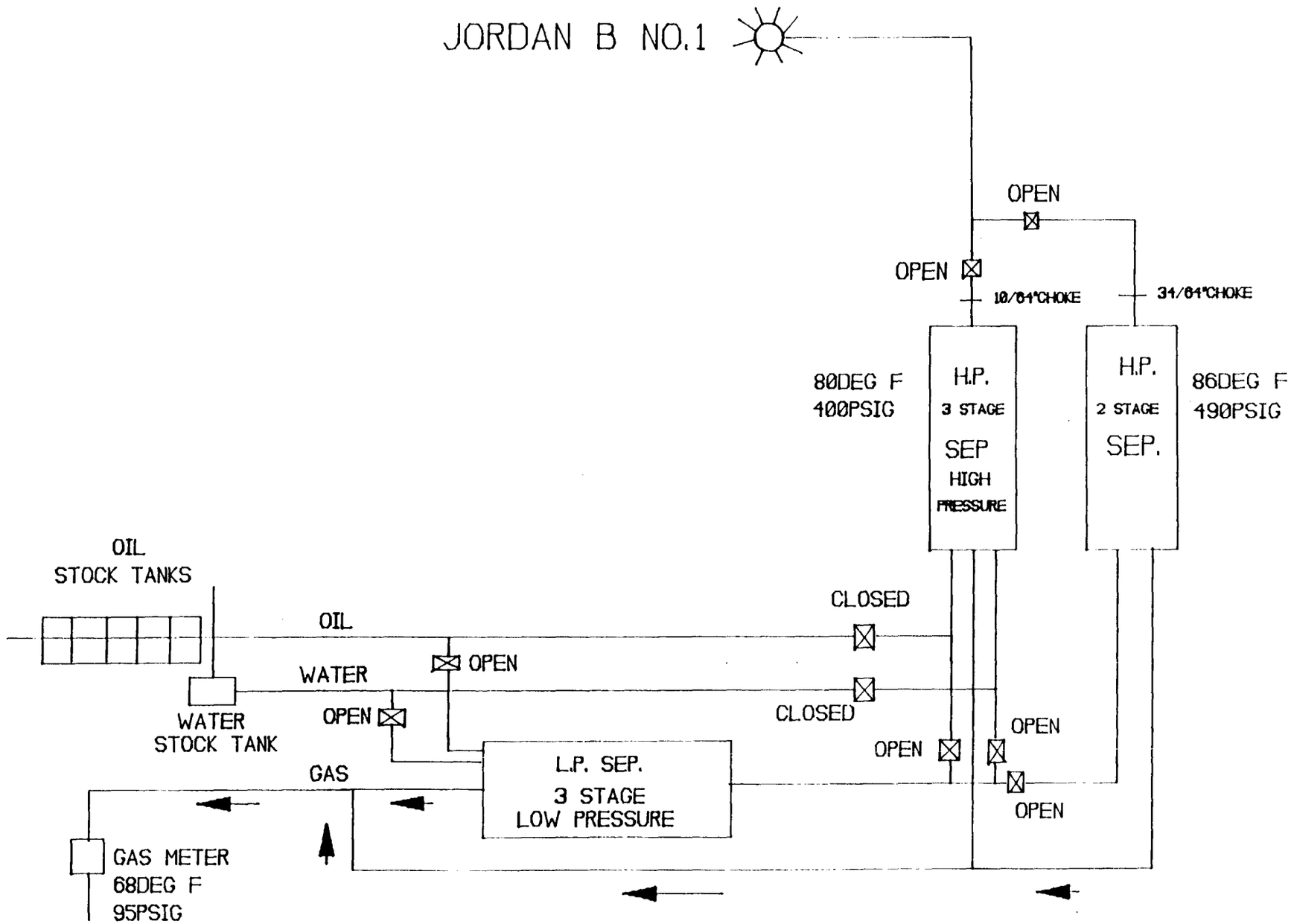
Table 9
Constant Volume Depletion Study at 152 °F
Compositions of Produced Wellstreams - Mole Percent

Pressure (psia)	3912	2514	2012	1013	512
Component					
Nitrogen	1.166	1.095	1.155	1.113	1.156
Carbon Dioxide	0.198	0.170	0.135	0.125	0.128
Methane	76.914	79.413	80.015	79.882	77.834
Ethane	10.638	10.419	10.383	10.636	11.317
Propane	5.180	4.907	4.616	4.733	5.584
iso-Butane	0.793	0.683	0.654	0.651	0.779
n-Butane	1.819	1.480	1.407	1.398	1.685
iso-Pentane	0.594	0.421	0.393	0.368	0.441
n-Pentane	0.735	0.480	0.443	0.412	0.482
Hexanes	0.779	0.405	0.347	0.388	0.341
Heptanes-Plus	1.184	0.527	0.453	0.293	0.253
Total	100.000	100.000	100.000	100.000	100.000
Hexanes-Plus	1.963	0.932	0.800	0.682	0.595
Heptanes-Plus	1.184	0.527	0.453	0.293	0.253
Molecular Weight:					
Total	22.5	21.2	20.9	20.8	21.3
Hexanes-Plus	94	94	94	90	90
Heptanes-Plus	101	101	101	99	97
Compressibility Factor(z)	0.8387	0.7884	0.8004	0.8770	0.9315
Density (g/cm3)	0.2559	0.1645	0.1280	0.0586	0.0286
Cumulative moles produced (percentage of initial)	16.948	37.547	47.025	68.432	78.493

Table 10
Liquid Dropout
Constant Volume Depletion at 152 °F

Pressure (psia)	Liquid Volume Percent
3912	5.00
2514	11.16
2012	11.45
1013	10.01
512	8.74

Figure 1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PRESSURE
H.P.
2 STAGE
SEP.
86DEG F
490PSIG
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STOCK TANKS
CLOSED
OIL
OPEN
WATER
WATER
STOCK TANK
OPEN
CLOSED
OPEN
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Figure 2

Relative Volume

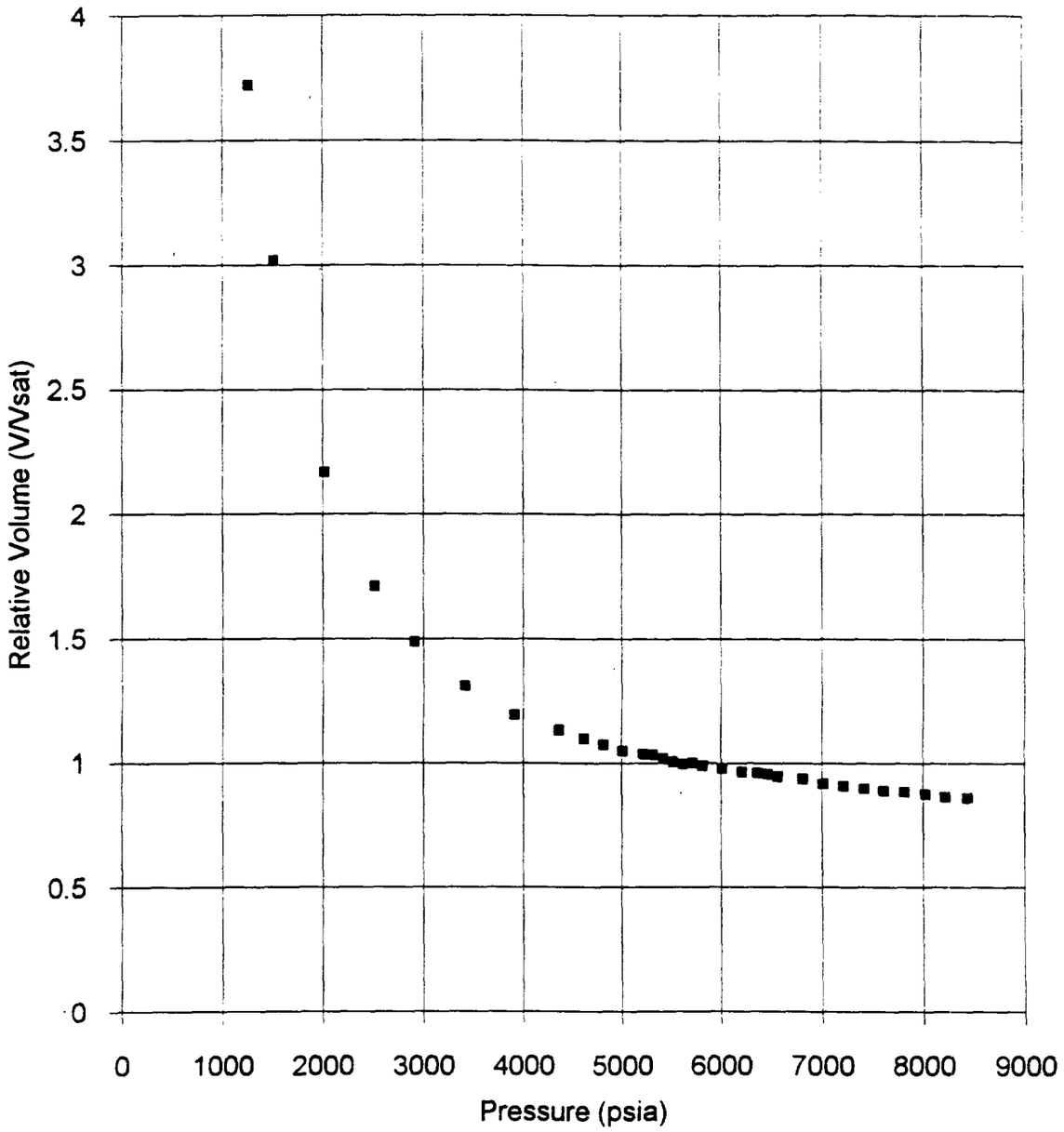


Figure 3

Compressibility Factor (z)

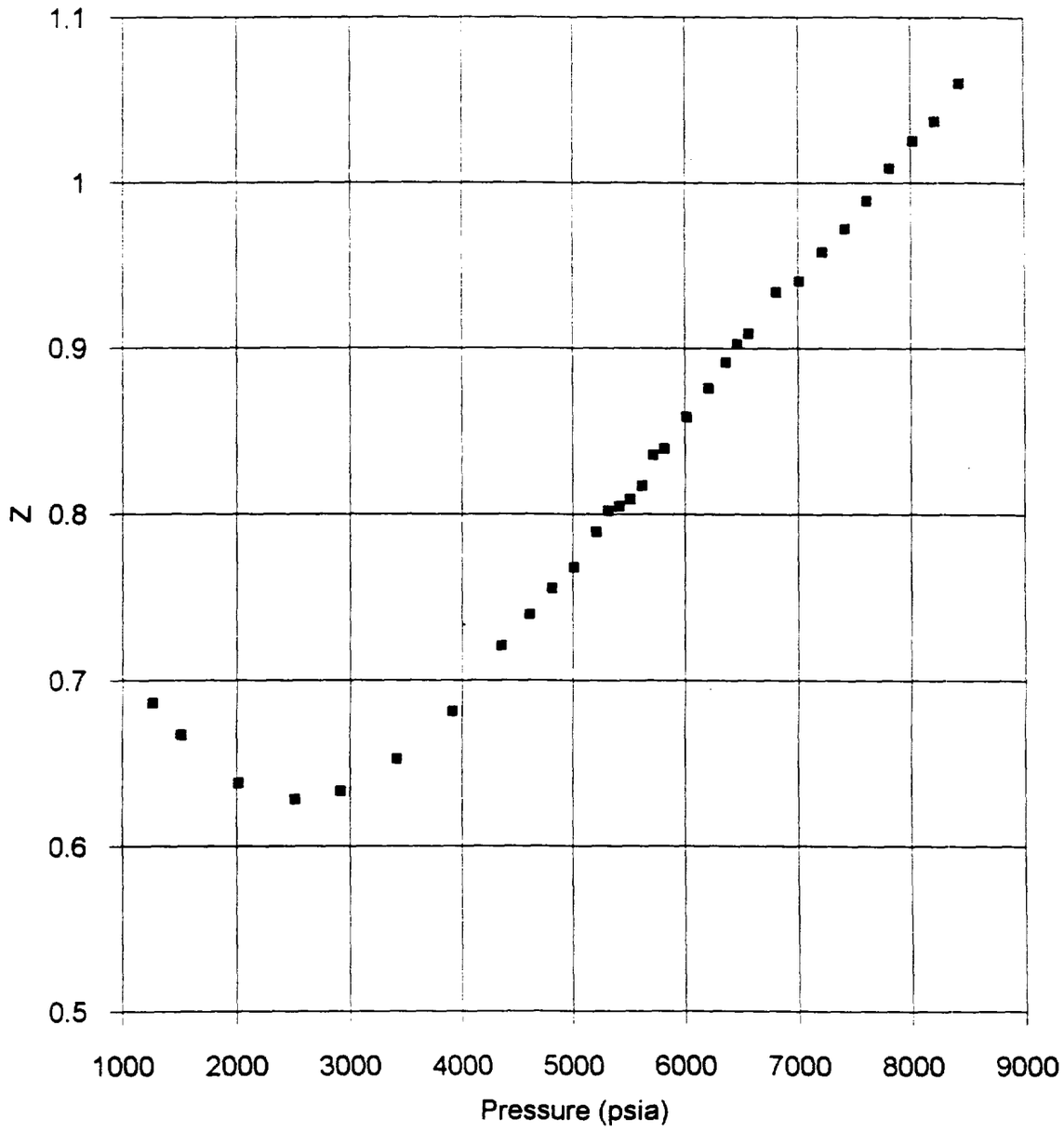


Figure 4

Liquid Dropout Curve
Constant Composition Expansion

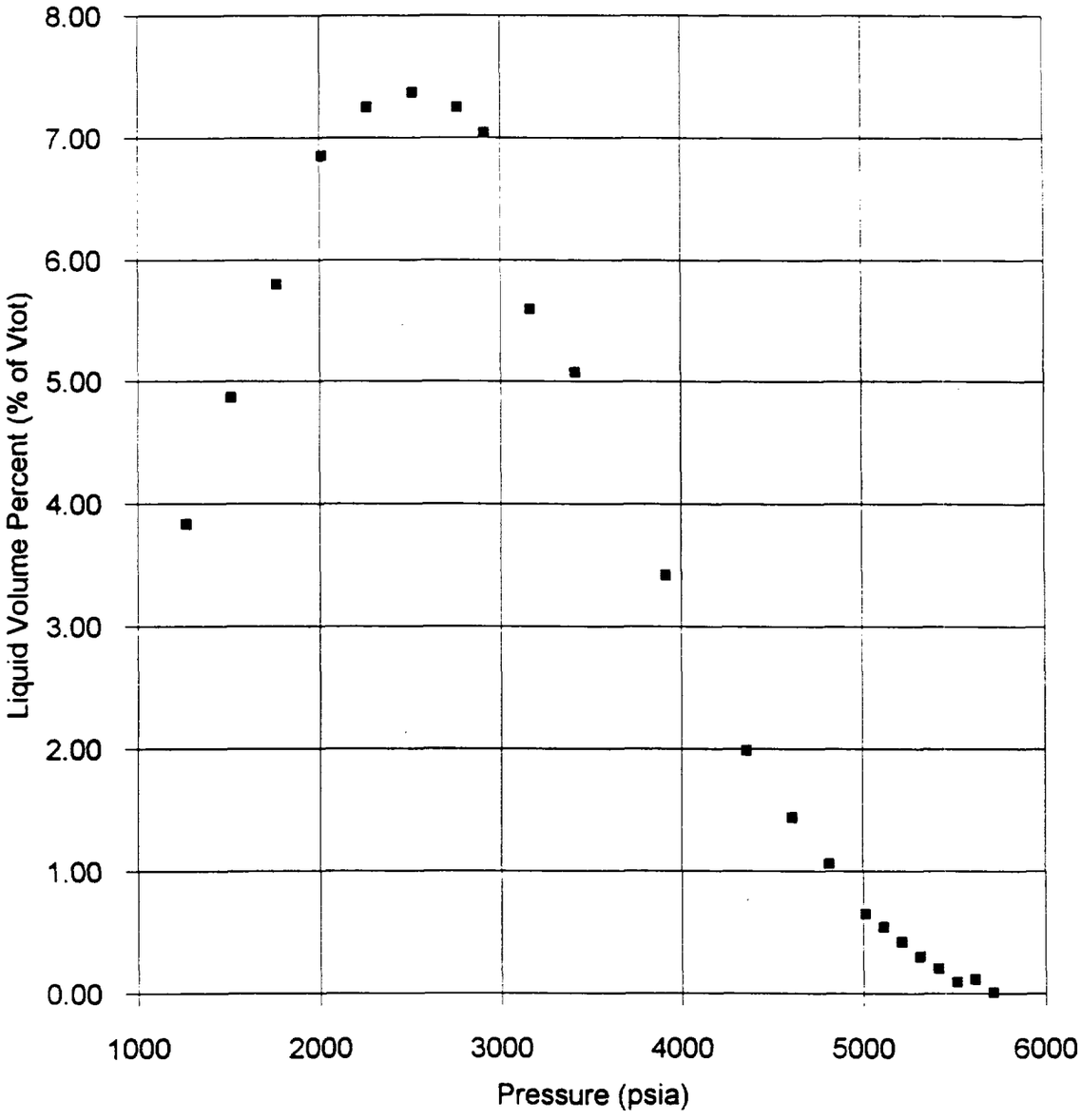
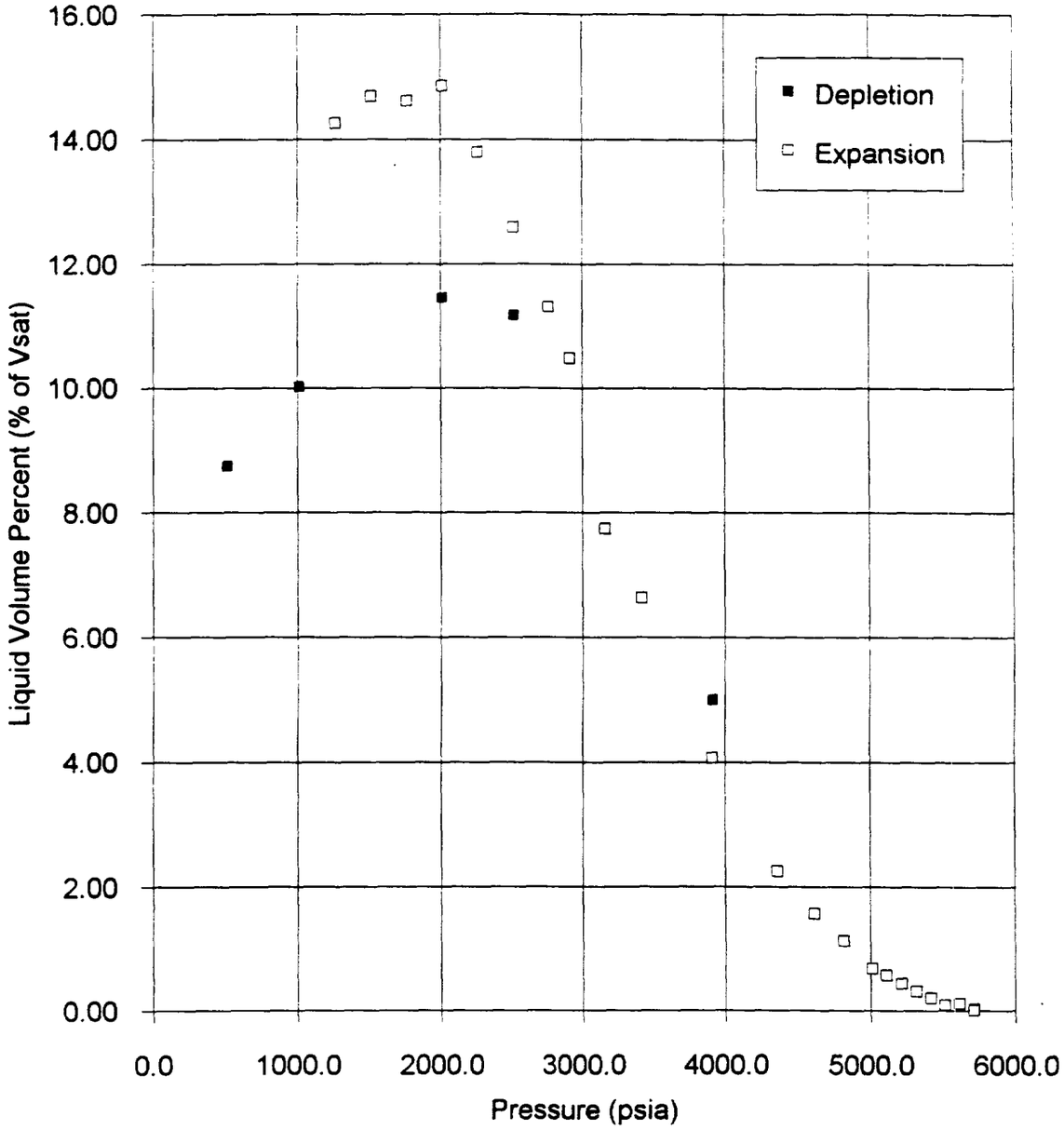


Figure 5

Liquid Dropout Curves



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