



# CORE LABORATORIES

Reservoir Fluid Study  
for  
**Arco Exploration & Production Technology**  
KUDW No. 2 Well

20 NOV 1993

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DATE \_\_\_\_\_

RFL 930193  
22-Oct-93

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October 22, 1993

Arco Exploration and Production Technology  
2300 West Plano Parkway  
Rm PRC -E1304  
Plano, TX 75075

ATTENTION: Mr. Russ Bone

**Subject: Reservoir Fluid Study**  
**Well: KUDW No. 2**  
**File: RFL 930193**

Dear Mr. Bone,

A sample of subsurface fluid was collected from the subject well by representatives of Arco Exploration and Production Technology. This sample was shipped to our laboratory in Carrollton, Texas for use in a reservoir fluid study. The results of this study are presented on the following pages.

It has been a pleasure to perform this reservoir fluid study for Arco Exploration and Production Technology. Should any questions arise or if we may be of further service in any way, please do not hesitate to contact us.

Sincerely,

A handwritten signature in cursive script that reads "Karl W. Karnes".

Karl W. Karnes  
Supervising Engineer  
Reservoir Fluid Analysis

KWK  
16 cc: Addressee  
15 bound & 1 unbound

Dallas Advanced Technology Center

1875 Monetary Drive, Carrollton, Texas 75006-7012, (214) 466-2673, Telex 163166, CORDAL UT, Fax (214) 323-3930

## Laboratory Procedures

Arco Exploration & Production Technology  
Reservoir Fluid Study  
KUDW No. 2 Well

RFL 930193

On September 29, 1993, a sample of subsurface fluid was received in our Carrollton, Texas laboratory. A bubblepoint determination of the liquid sample was measured at reservoir temperature as a quality check. A summary of samples received in the laboratory may be found on page four.

The composition of the reservoir fluid was measured through a heptanes plus residual fraction by low temperature fractional distillation. The heptanes plus fraction was further analyzed by gas chromatography through hexatriacontanes plus. The composition and density of the fluid can be found on pages five through seven.

A portion of the reservoir fluid was charged to a high pressure, windowed cell heated to the reported reservoir temperature of 119°F. During the constant composition expansion at this temperature, a bubblepoint was observed at 2607 psig. The results of the pressure-volume relations are presented on pages eight and nine.

During the differential vaporization at the reservoir temperature, the fluid evolved a total of 344 cubic feet of gas at 14.65 psia and 60°F per barrel of residual oil at 60°F. The resulting relative oil volume factor was 1.148 barrels of saturated fluid per barrel of residual oil at 60°F. The oil density and the properties of the evolved gases were measured at each point during the differential pressure depletion and the data included in the summary of the differential vaporization data on page ten.

The viscosity of the reservoir fluid was measured over a wide range of pressures at 119°F in a rolling ball viscometer. The viscosity of the fluid was found to vary from a minimum of 3.90 centipoises at the saturation pressure to a maximum of 12.8 centipoises at atmospheric pressure. The results of the viscosity measurements are presented on page 11.

Small portions of the reservoir fluid were subjected to three multi-stage separator tests to determine the effects of separator pressure and temperature on gas/oil ratio, stock tank oil gravity and formation volume factor. These data can be found on page 12. The gases evolved from the "base case" separator test were analyzed through undecanes and are reported on pages 14 and 15. The associated stock tank oil composition can be found on page 16. The three separator test data were used to adjust the differential vaporization data to surface conditions and are summarized on pages 17 through 19.

A large portion of reservoir fluid was charged to a PVT cell at 119°F. From this sample three gas depleted oils were prepared at specified saturation pressures. A separator test was performed on the individual "DV" oils at the same conditions as the "base case" multi-stage separator test investigated above. The results of these analyses are presented on page 13.

Equations and nomenclature are included in the appendix of the report which extend and define the analytical expressions and data relationships presented in the study.

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**SUMMARY OF PVT DATA**

**Reported Reservoir Conditions**

Average Reservoir Pressure .....	3190	psig
Average Reservoir Temperature .....	119	°F

**Pressure-Volume Relations**

Saturation Pressure .....	2607	psig
Avg Single-Phase Compressibility .....	6.31	E-6 v/v/psi ( 3190 to 2607 psig )

**Differential Vaporization Data**

( at 2607 psig and 119 °F )

Solution Gas/Oil Ratio .....	344	scf / bbl of residual oil at 60 °F
Relative Oil Volume .....	1.148	bbl / bbl of residual oil at 60 °F
Density of Reservoir Fluid .....	0.8135	gm/cc

**Reservoir Fluid Viscosity**

3.90 cp at 2607 psig and 119 °F
---------------------------------

**Separator Test Results**

Separator Conditions		Formation Volume Factor (A)	Total Solution Gas/Oil Ratio (B)	Tank Oil Gravity ( °API at 60 °F )
psig	°F			
100	90	1.149	337	27.2
100	140	1.151	338	27.2
500	90	1.144	324	27.5
Prepared Differential Vaporization Oils				
100	90	1.131	285	27.3
100	90	1.101	193	27.3
100	90	1.070	112	27.4

(A) Barrels of saturated oil per barrel of stock tank oil at 60 °F.

(B) Total standard cubic feet of gas per barrel of stock tank oil at 60 °F.

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**General Well Information**

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Company.....	<b>Arco Exploration &amp; Production Technology</b>
Well Name.....	<b>KUDW No. 2 Well</b>
API Well Number.....	*
File Number.....	<b>RFL 930193</b>
Date Sample Collected.....	*
Sample Type.....	<b>Bottom-Hole</b>
Geographical Location.....	*
Field.....	*

**Well Description**

---

Formation.....	*	
Pool (or Zone).....	*	
Date Completed.....	*	
Elevation.....	*	ft
Producing Interval.....	*	ft
Total Depth.....	*	ft
Tubing Size.....	*	in
Tubing Depth.....	*	ft
Casing Size.....	*	in
Casing Depth.....	*	ft

**Pressure Survey Data**

---

**Data from Original Discovery Well**

Date .....	*	
Reservoir Pressure .....	*	psig
Gas / Oil Contact.....	*	ft
Oil / Water Contact.....	*	ft

**Data at Sample Collection**

Date.....	*	
Reservoir Pressure.....	<b>3190</b>	psig
Reservoir Temperature.....	<b>119</b>	°F
Pressure Tool.....	*	
Flowing Bottom-Hole Pressure.....	*	psig
Gas / Oil Contact.....	*	ft
Oil / Water Contact.....	*	ft

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\* Data not forwarded to Core Laboratories.

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**Production Data**

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**Data from Original Discovery Well**

Location.....	*		
Date.....	*		
Oil Gravity @ STP.....	*		°API
Separator Pressure.....	*		psig
Separator Temperature.....	*		°F
Production Rates			
Gas.....	*		Mscf/D
Liquid.....	*		STbbl/D
Gas/Liquid Ratio.....	*		scf/bbl

**Data at Sample Collection**

Sampling Date.....	*		
Production Rate.....	*		bb/D
Produced G.O.R. ....	*		scf/bbl
Liquid Gravity at 60.0 °F.....	*		°API
Productivity Index.....	*		bb/D/psi at and °F bbl/D

**Sampling Information**

Sample Collected at.....	*		ft
Status of Well.....	*		
Sampled By.....	*		
Type Sampler.....	*		
Cylinder Names/Numbers .....		<b>93A00395</b>	

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\* Data not forwarded to Core Laboratories.

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**PRELIMINARY QUALITY CHECKS**  
**PERFORMED ON SAMPLES RECEIVED IN LABORATORY**

Cylinder Number	Sampling Date	Sampling Conditions		Bubblepoint Conditions		Approximate Sample Volume (cc)	Water Recovered (cc)
		psig	°F	psig	°F		
93A00395	*	*	*	2,572	119	490	0

\* Data not forwarded to Core Laboratories.

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**Composition of Reservoir Fluid**

( by Podbielniak / Toepler and extended gas chromatography )

Component	Mol %	Wt %	MW	Liq Dens (gm/cc)
Hydrogen	0.00			
Hydrogen Sulfide	0.00			
Carbon Dioxide	0.17	0.04	44.010	0.8172
Nitrogen	0.06	0.01	28.013	0.8086
Methane	41.71	3.87	16.043	0.2997
Ethane	1.05	0.18	30.070	0.3558
Propane	0.50	0.13	44.097	0.5065
i-Butane	0.24	0.08	58.123	0.5623
n-Butane	0.19	0.06	58.123	0.5834
i-Pentane	0.20	0.08	72.15	0.6241
n-Pentane	0.21	0.09	72.15	0.6305
Hexanes	0.83	0.40	84.00	0.6850
Heptanes plus	54.84	95.05	300.00	0.8946
	100.00	100.00		

**Sample Characteristics**

This is Core Lab sample number 805

Average Molecular Weight ..... 488.7

Sample Density (at 60 °F) ..... 0.8258

Note: Heptanes plus MW and Density are measured values.

Data corrected for benzene and hexanes minus fraction identified in residue analysis.

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**Composition of Heptanes Plus Fraction**

( From Chromatographic Technique )

Component	Mol %	Wt %	Density (gm/cc)	MW	Vol %
Hydrogen Sulfide	.00	.00			
Carbon Dioxide	.00	.00			
Nitrogen	.00	.00			
Methane	.00	.00			
Ethane	.00	.00			
Propane	.00	.00			
iso-Butane	.00	.00			
n-Butane	.00	.00			
iso-Pentane	.00	.00			
n-Pentane	.00	.00			
Hexanes	.00	.00			
Heptanes	1.72	.55	.722	96.0	0.68
Octanes	3.67	1.31	.745	107.0	1.57
Nonanes	3.97	1.60	.764	121.0	1.87
Decanes	4.72	2.11	.778	134.0	2.42
Undecanes	4.37	2.14	.789	147.0	2.42
Dodecanes	4.38	2.35	.800	161.0	2.63
Tridecanes	5.45	3.18	.811	175.0	3.51
Tetradecanes	5.70	3.61	.822	190.0	3.93
Pentadecanes	6.43	4.41	.832	206.0	4.74
Hexadecanes	4.92	3.64	.839	222.0	3.88
Heptadecanes	4.77	3.77	.847	237.0	3.98
Octadecanes	4.81	4.02	.852	251.0	4.22
Nonadecanes	3.95	3.46	.857	263.0	3.61
Eicosanes	3.87	3.55	.862	275.0	3.69
Heneicosanes	3.05	2.96	.867	291.0	3.05
Docosanes	2.93	2.98	.872	305.0	3.06
Tricosanes	2.60	2.76	.877	318.0	2.82
Tetracosanes	2.35	2.59	.881	331.0	2.63
Pentacosanes	2.34	2.69	.885	345.0	2.72
Hexacosanes	1.78	2.13	.889	359.0	2.15
Heptacosanes	1.89	2.36	.893	374.0	2.36
Octacosanes	1.77	2.29	.896	388.0	2.29
Nonacosanes	1.82	2.44	.899	402.0	2.42
Triacontanes	1.95	2.70	.902	416.0	2.67
Hentriacontanes	1.74	2.49	.906	430.0	2.46
Dotriacontanes	1.15	1.70	.909	444.0	1.67
Tritriacontanes	1.10	1.68	.912	458.0	1.65
Tetracontanes	.99	1.56	.914	472.0	1.53
Pentatriacontanes	.99	1.61	.917	486.0	1.57
Hexatriacontanes plus	8.82	25.36	1.042	862.6	21.77
<b>Totals</b>	<b>100.00</b>	<b>100.00</b>			<b>100.00</b>

**Sample Characteristics**

This is Core Lab sample number 610

Total Liquid Molecular Weight .....	300.0
Total Liquid Density (gm/cc) .....	0.8947
Total Liquid API Gravity .....	26.5
 Benzene (Wt %) .....	 0.0

**Properties of Heavy Fractions**

Plus Fractions	Mol %	Wt %	Density (gm/cc)	*API	MW
Heptanes plus	100.00	100.00	0.895	26.5	300.0
Decanes plus	90.64	96.54	0.901	25.4	319.5
Undecanes plus	85.92	94.43	0.904	24.9	329.7
Pentadecanes plus	66.02	83.15	0.919	22.3	377.8
Eicosanes plus	41.14	63.85	0.944	18.2	465.5
Pentacosanes plus	26.34	49.01	0.969	14.5	558.2
Triacontanes plus	16.74	37.10	0.996	10.4	664.9
Pentatriacontanes plus	9.81	26.97	1.034	5.3	824.6

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**Composition of Low Temperature Distillation Residue**

( From Chromatographic Technique )

Component	Mol %	Wt %	Density (gm/cc)	MW	Vol %
Hydrogen Sulfide	.00	.00			
Carbon Dioxide	.00	.00			
Nitrogen	.00	.00			
Methane	.00	.00			
Ethane	.00	.00			
Propane	.00	.00			
iso-Butane	.00	.00			
n-Butane	.00	.00			
iso-Pentane	.21	.05	.624	72.2	0.07
n-Pentane	.21	.05	.630	72.2	0.07
Hexanes	.95	.27	.685	84.0	0.35
Heptanes	1.70	.55	.722	96.0	0.68
Octanes	3.64	1.31	.745	107.0	1.57
Nonanes	3.90	1.59	.764	121.0	1.86
Decanes	4.65	2.10	.778	134.0	2.41
Undecanes	4.30	2.13	.789	147.0	2.41
Dodecanes	4.32	2.34	.800	161.0	2.62
Tridecanes	5.38	3.17	.811	175.0	3.49
Tetradecanes	5.63	3.60	.822	190.0	3.91
Pentadecanes	6.32	4.38	.832	206.0	4.72
Hexadecanes	4.86	3.63	.839	222.0	3.87
Heptadecanes	4.71	3.76	.847	237.0	3.97
Octadecanes	4.74	4.01	.852	251.0	4.21
Nonadecanes	3.90	3.45	.857	263.0	3.60
Eicosanes	3.82	3.54	.862	275.0	3.67
Heneicosanes	3.01	2.95	.867	291.0	3.04
Docosanes	2.89	2.97	.872	305.0	3.05
Tricosanes	2.57	2.75	.877	318.0	2.81
Tetracosanes	2.31	2.58	.881	331.0	2.62
Pentacosanes	2.31	2.68	.885	345.0	2.71
Hexacosanes	1.75	2.12	.889	359.0	2.13
Heptacosanes	1.87	2.35	.893	374.0	2.35
Octacosanes	1.75	2.28	.896	388.0	2.27
Nonacosanes	1.80	2.43	.899	402.0	2.41
Triacontanes	1.92	2.69	.902	416.0	2.66
Hentriacontanes	1.71	2.48	.906	430.0	2.45
Dotriacontanes	1.13	1.69	.909	444.0	1.66
Tritriacontanes	1.08	1.67	.912	458.0	1.63
Tetracontanes	.98	1.55	.914	472.0	1.52
Pentatriacontanes	.98	1.60	.917	486.0	1.55
Hexatriacontanes plus	8.70	25.28	1.042	862.6	21.67
<b>Totals</b>	<b>100.00</b>	<b>100.00</b>			<b>100.00</b>

**Sample Characteristics**

This is Core Lab sample number 609

Total Liquid Molecular Weight .....	297.0
Total Liquid Density (gm/cc) .....	0.8935
Total Liquid API Gravity .....	26.7
 Benzene (Wt %) .....	 0.0

**Properties of Heavy Fractions**

Plus Fractions	Mol %	Wt %	Density (gm/cc)	*API	MW
Hexanes plus	99.58	99.90	0.894	26.6	297.9
Heptanes plus	98.63	99.63	0.895	26.5	300.0
Decanes plus	89.39	96.18	0.901	25.4	319.6
Undecanes plus	84.74	94.08	0.904	24.9	329.7
Pentadecanes plus	65.11	82.84	0.919	22.3	377.9
Eicosanes plus	40.58	63.61	0.944	18.3	465.5
Pentacosanes plus	25.98	48.82	0.968	14.5	558.2
Triacontanes plus	16.50	36.96	0.996	10.5	665.1
Pentatriacontanes plus	9.68	26.88	1.033	5.3	824.5

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**KUDW No. 2 Well**

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**VOLUMETRIC DATA**

(at 119 °F)

Saturation Pressure (Psat)	2607	psig
Density at Psat	0.8135	gm/cc

**AVERAGE SINGLE-PHASE COMPRESSIBILITIES**

Pressure Range psig	Single-Phase Compressibility v/v/psi
------------------------	--

5000	to	4500	5.36 E -6
4500	to	4000	5.62 E -6
4000	to	3500	5.89 E -6
3500	to	3000	6.15 E -6
3000	to	2607	6.35 E -6

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**PRESSURE-VOLUME RELATIONS**

(at 119 °F)

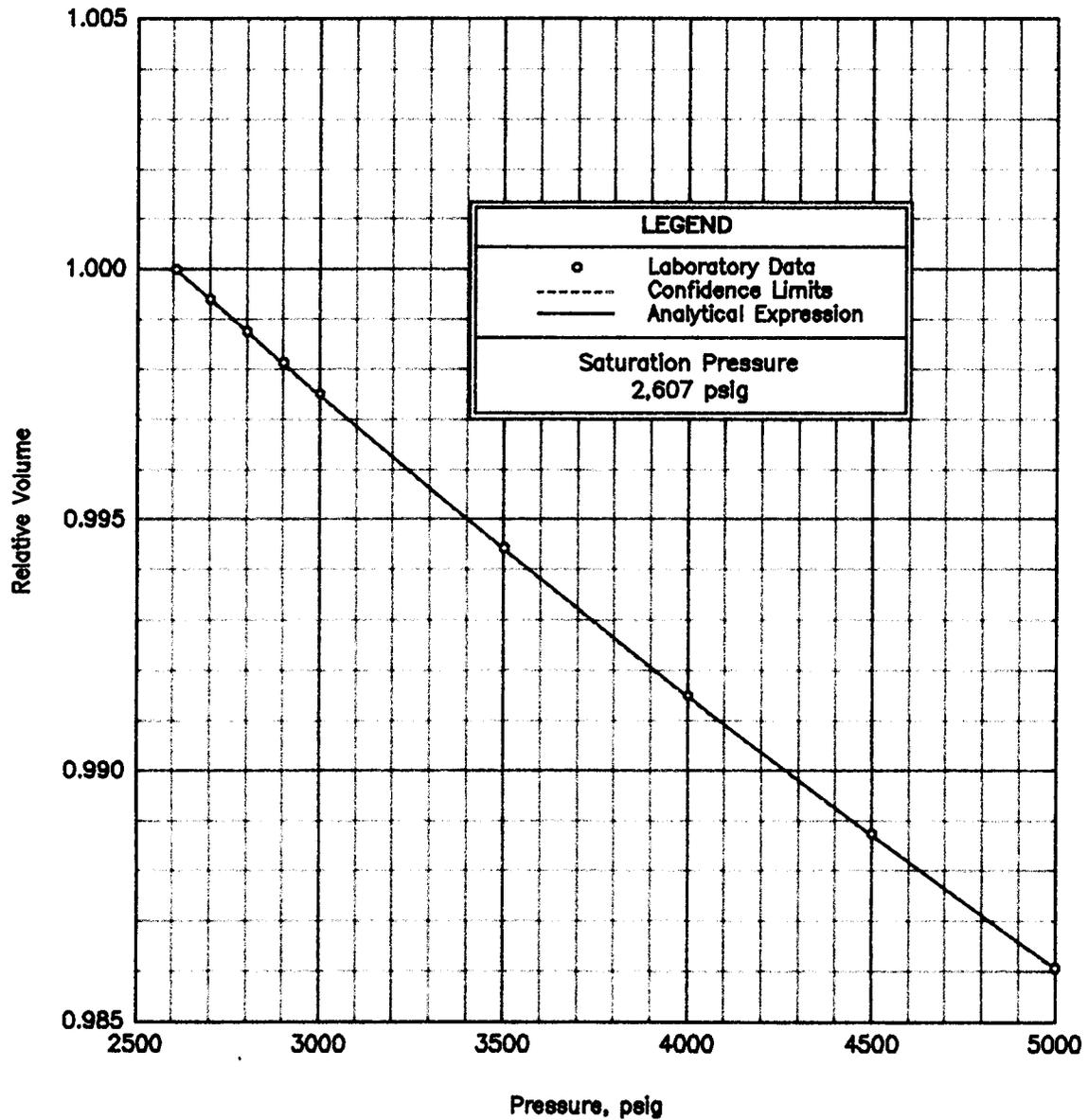
Pressure psig	Relative Volume (A)	Y-Function (B)	Density gm/cc
5000	0.9861		0.8250
4500	0.9887		0.8228
4000	0.9915		0.8204
3500	0.9944		0.8180
3000	0.9975		0.8155
2900	0.9981		0.8150
2800	0.9988		0.8145
2700	0.9994		0.8140
b>2607	1.0000		0.8135
2599	1.0006		
2577	1.0022		
2557	1.0036		
2542	1.0048		
2530	1.0057		
2446	1.0123		
2321	1.0234	5.234	
2123	1.0445	5.086	
1898	1.0761	4.871	
1679	1.1183	4.633	
1440	1.1841	4.358	
1228	1.2696	4.115	
1044	1.3775	3.911	
889	1.5073	3.747	
745	1.6804	3.602	
643	1.8522	3.504	
480	2.2811	3.357	
346	2.9330	3.243	
234	4.0258	3.154	

(A) Relative Volume:  $V/V_{sat}$  or volume at indicated pressure per volume at saturation pressure.

(B) Where: Y-Function = 
$$\frac{(P_{sat} - P)}{(P_{abs}) * (V/V_{sat} - 1)}$$

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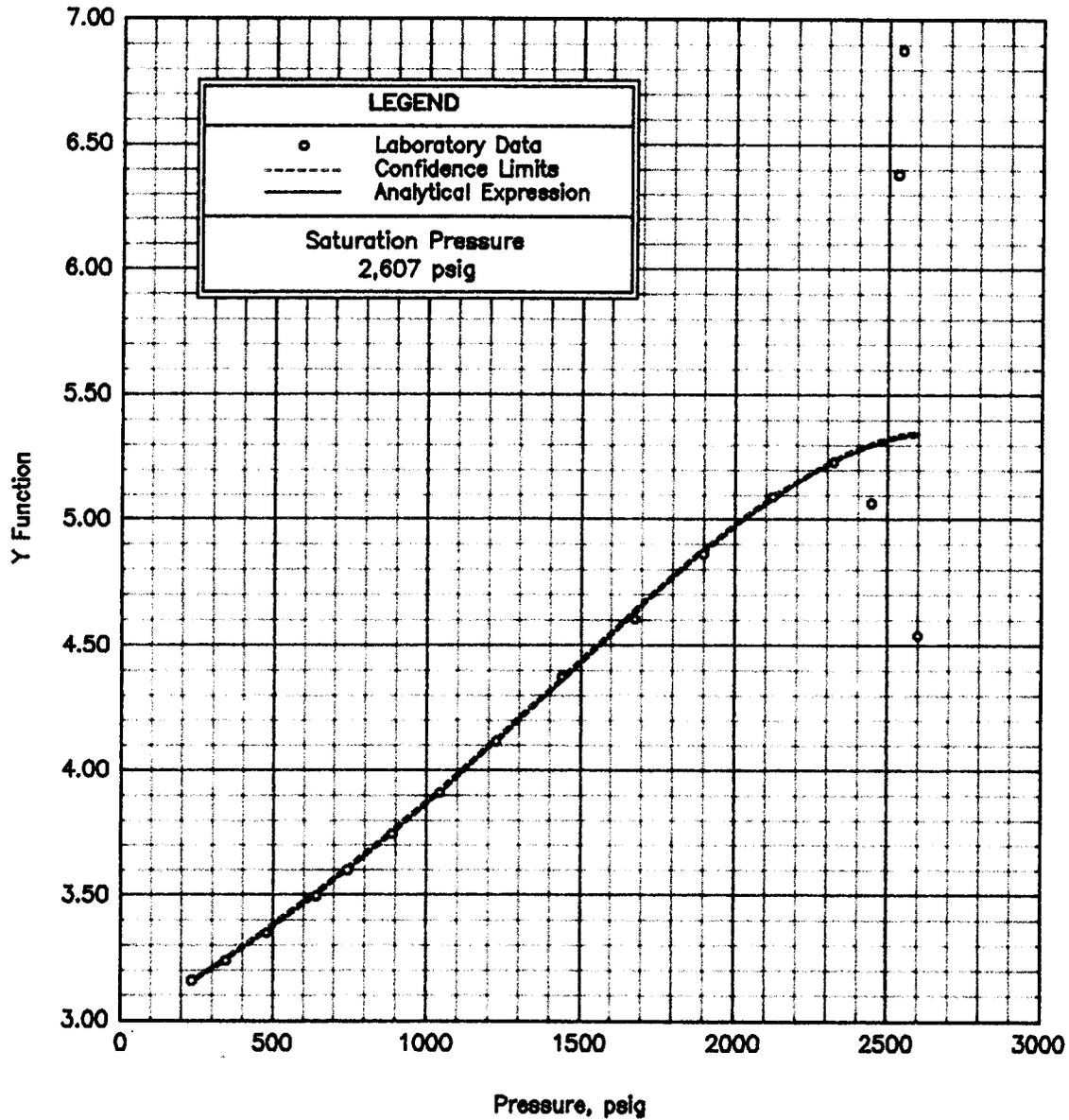
RELATIVE VOLUME  
 ( at 119 °F )



<b>Analytical Expression</b> $1 - 10^{-5.195E00 + 1.001E00 (\log(dP)) + -7.371E-07 (\log(dP))^9}$ Note: dP is defined as   P1 - Pcat  , psig	
<b>Statistical Summary</b>	<b>Pressure-Volume Relations</b> <b>Figure A-1</b>
r squared: 0.999997 Confidence Interval (+/-): 0.0000 Confidence: 99 %	

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Y-FUNCTION  
 ( at 119 °F )



<b>Analytical Expression</b> $1 / ( 3.351E-01 + -1.987E-01 (X_d) + -3.234E-02 (X_d)^2 + 8.286E-02 (X_d)^3 )$ Note: $X_d$ is defined as $P_i / P_{sat}$	
<b>Statistical Summary</b>	<b>Pressure-Volume Relations</b> <b>Figure A-2</b>
r squared:                    0.999738 Confidence Interval (+/-): 0.0086 Confidence:                    98 %	

**Arco Exploration & Production Technology**  
**KUDW No. 2 Well**  
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**DIFFERENTIAL VAPORIZATION**  
(at 119 °F)

Pressure psig	Solution Gas/Oil Ratio Rsd (A)	Relative Oil Volume Bod (B)	Relative Total Volume Btd (C)	Oil Density gm/cc	Deviation Factor Z	Gas Formation Volume Factor (D)	Incremental Gas Gravity (Air=1.000)
b»2607	344	1.148	1.148	0.8135			
2200	293	1.131	1.188	0.8204	0.862	0.00635	0.578
2000	269	1.122	1.217	0.8238	0.874	0.00707	0.578
1750	238	1.112	1.268	0.8281	0.888	0.00821	0.578
1500	206	1.101	1.340	0.8326	0.903	0.00972	0.579
1250	175	1.090	1.447	0.8371	0.918	0.01184	0.580
1000	143	1.080	1.617	0.8417	0.933	0.01501	0.583
800	117	1.071	1.837	0.8455	0.946	0.01894	0.585
500	77	1.057	2.516	0.8514	0.966	0.03061	0.592
250	41	1.045	4.323	0.8568	0.984	0.06063	0.604
0	0	1.026		0.8663			0.719
	@ 60 °F = 1.000						

Gravity of Residual Oil = 27.5 °API at 60 °F  
Density of Residual Oil = 0.8891 gm/cc at 60 °F

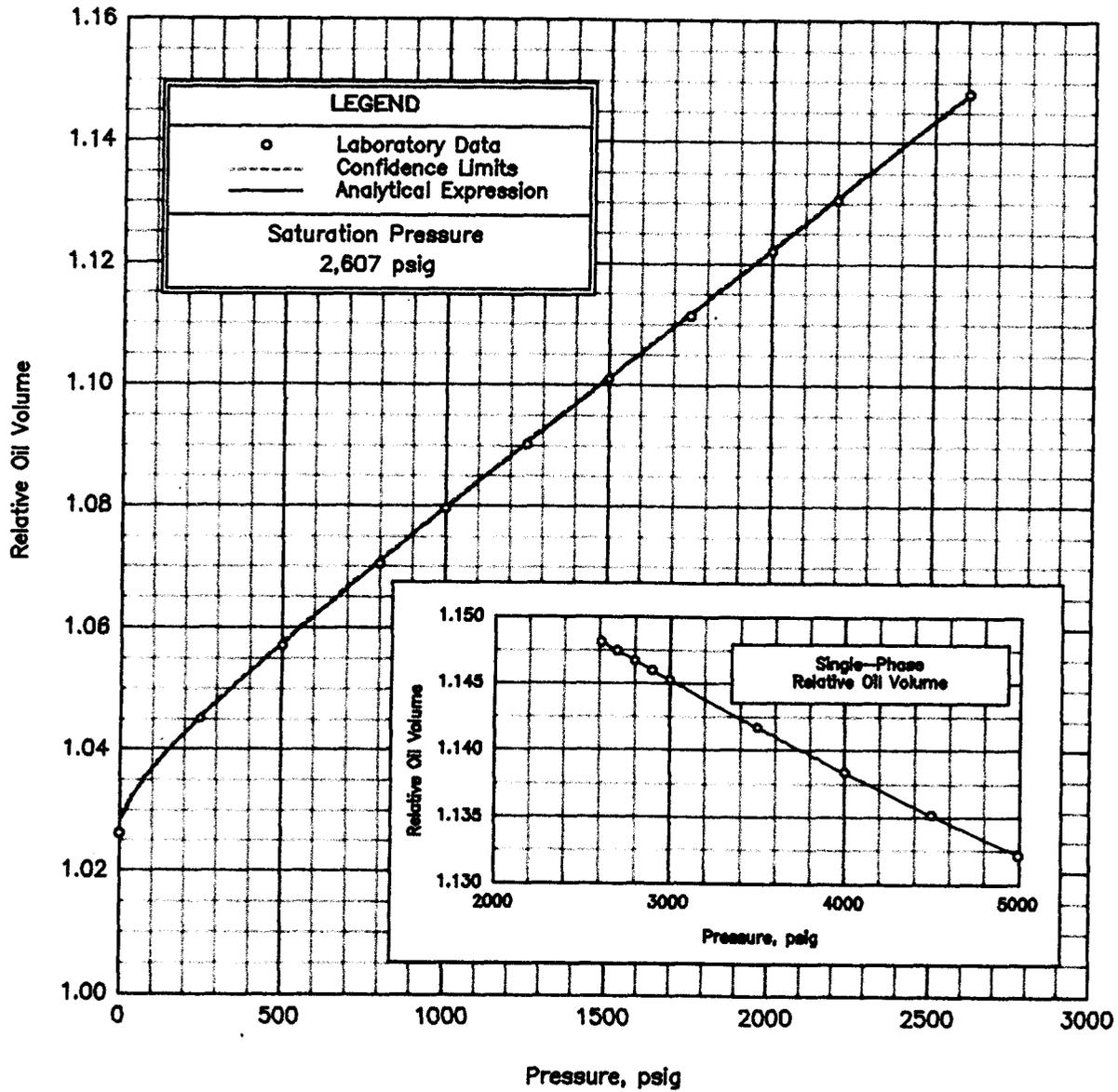
- (A) Cubic Feet of gas at 14.65 psia and 60 °F per Barrel of residual oil at 60 °F.  
(B) Barrel of oil at indicated pressure and temperature per Barrel of residual oil at 60 °F.  
(C) Barrels of oil plus liberated gas at indicated pressure and temperature per Barrel of residual oil at 60 °F.  
(D) Cubic Feet of gas at indicated pressure and temperature per Cubic Feet at 14.65 psia and 60 °F.

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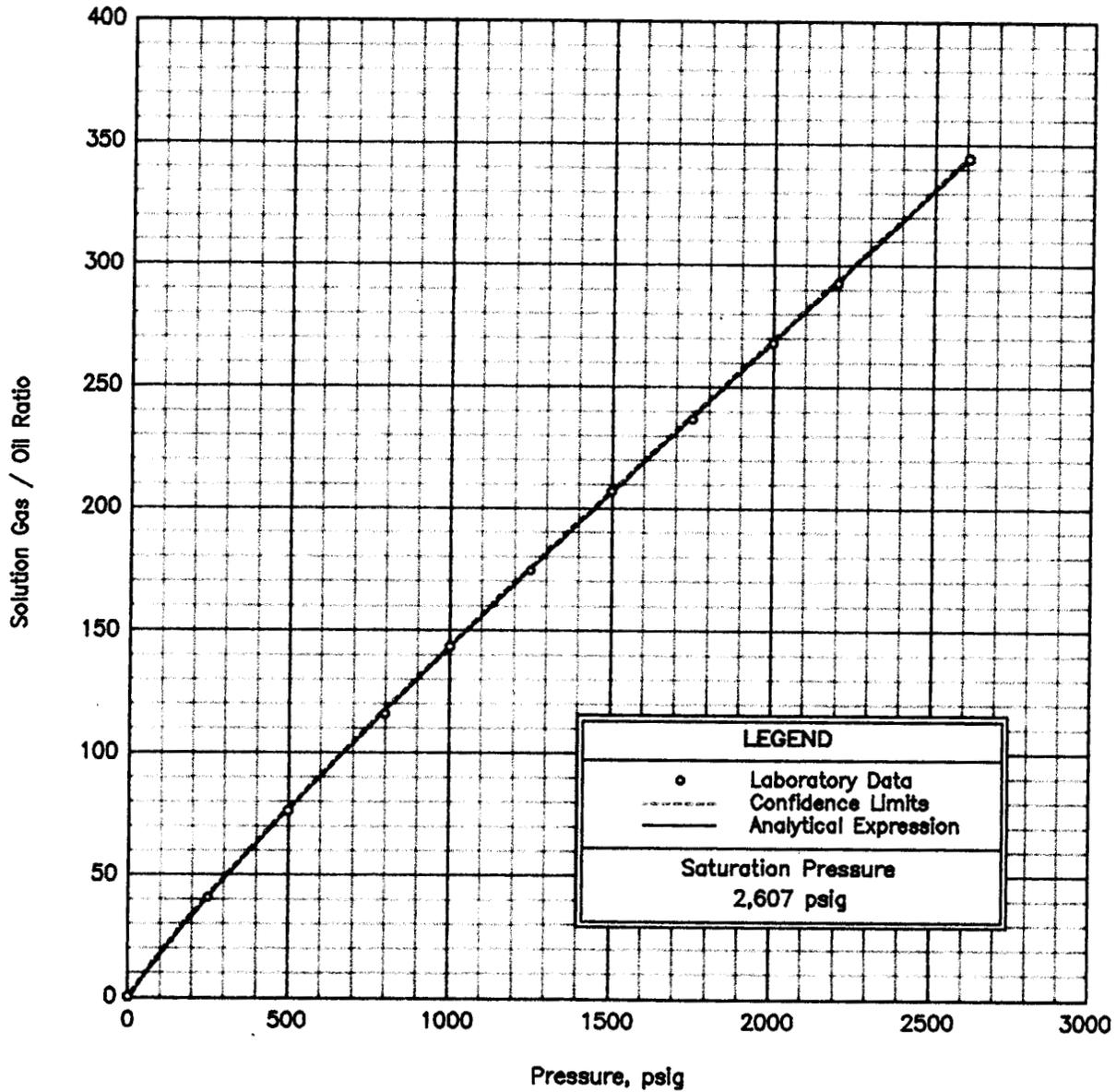
RELATIVE OIL VOLUME  
( at 119 °F )



Analytical Expression (below bubblepoint) $1.026E00 + 1.351E-05 (P_i)^{-1.1} + 8.190E-04 (P_i)^{-0.5} + 3.844E-10 (P_i)^{-2}$	
Note: $P_i$ is defined as pressure, psig	
<b>Statistical Summary</b>	<b>Differential Vaporization</b> Figure B-1
r squared: 0.999995	
Confidence Interval (+/-): .0001 Confidence: 99 %	

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SOLUTION GAS/OIL RATIO  
 ( scf/bbl at 119 °F )



Analytical Expression (below bubblepoint)

$$6.921E-01 (P_i)^{-0.8} + -1.069E00 (P_i)^{-0.5} + 7.498E-07 (P_i)^{-2.2}$$

Note:  $P_i$  is defined as pressure, psig

Statistical Summary

r squared: 0.999976  
 Confidence Interval (+/-): 1  
 Confidence: 99 %

Differential Vaporization

Figure B-2

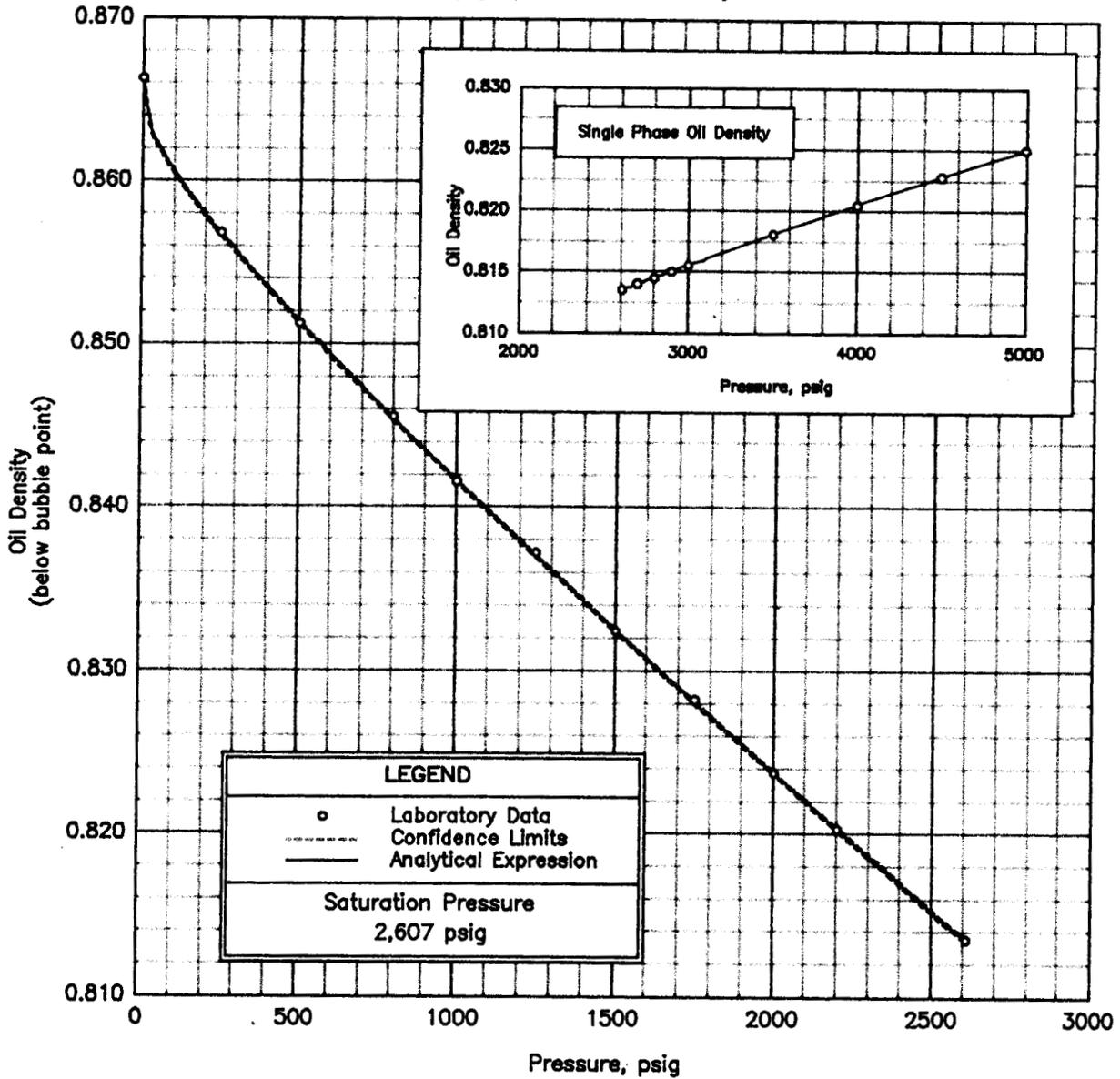
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OIL DENSITY

( gm/cc at 119 °F )



Analytical Expression (below bubblepoint)

$$0.86627 + -1.021E-03 ( P_i )^{-0.3} + -1.673E-05 ( P_i )^{-1} + 2.397E-10 ( P_i )^{-2}$$

Note: P<sub>i</sub> is defined as pressure, psig

Statistical Summary

r squared: 0.999969  
 Confidence Interval (+/-): 0.0001  
 Confidence: 99 %

Differential Vaporization

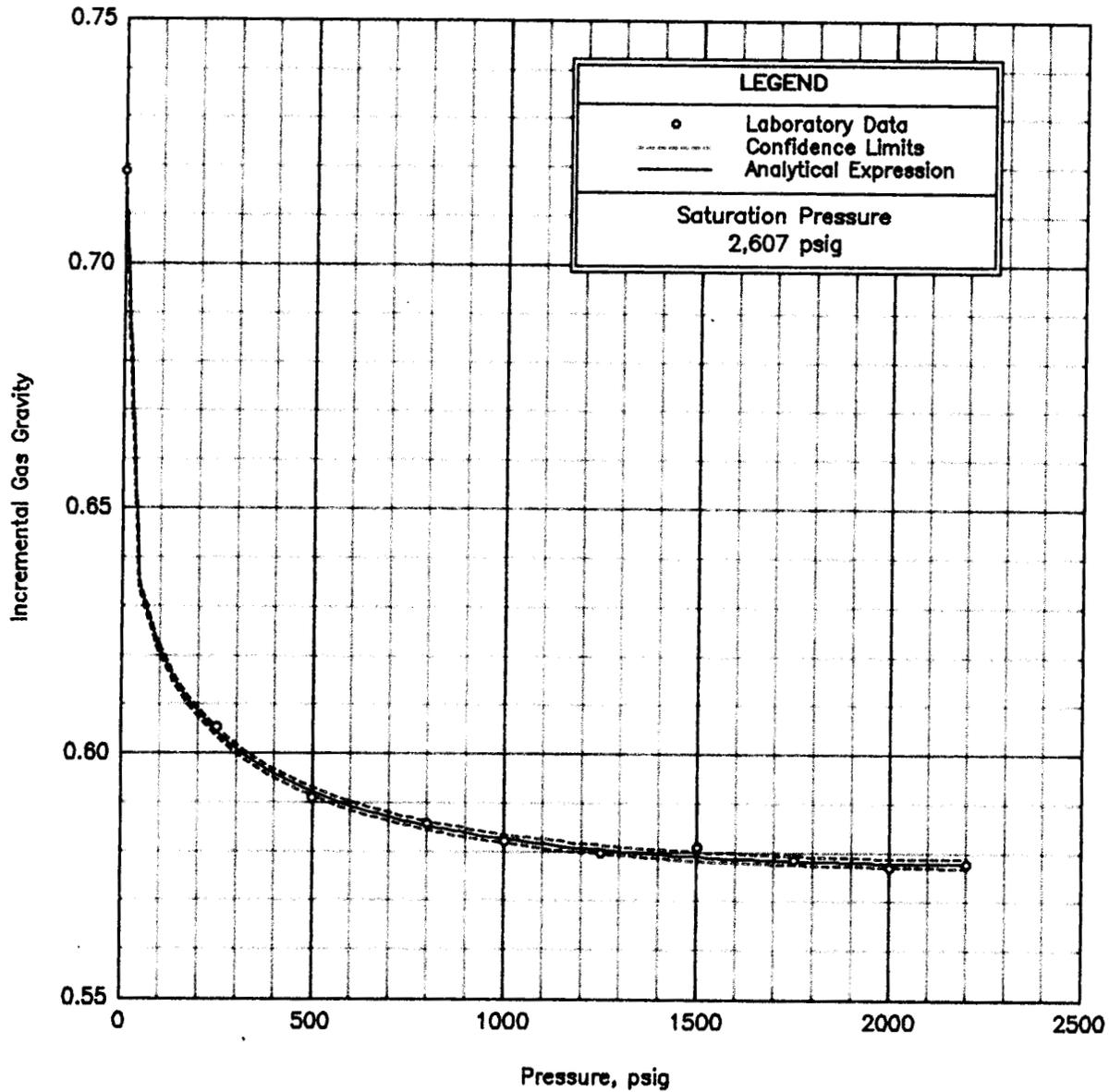
Figure B-3

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## GAS GRAVITY ( at 119 °F )



### Analytical Expression

$$7.811E-01 + -4.004E-02 ( P_i )^{-0.200} + 2.084E-07 ( P_i )^{-1.400} + -6.210E-02 ( \exp(-X_d) )$$

Note:  $X_d$  is defined as  $P_i / P_{sat}$

### Statistical Summary

r squared: 0.999553  
 Confidence Interval (+/-): 0.0009  
 Confidence: 99 %

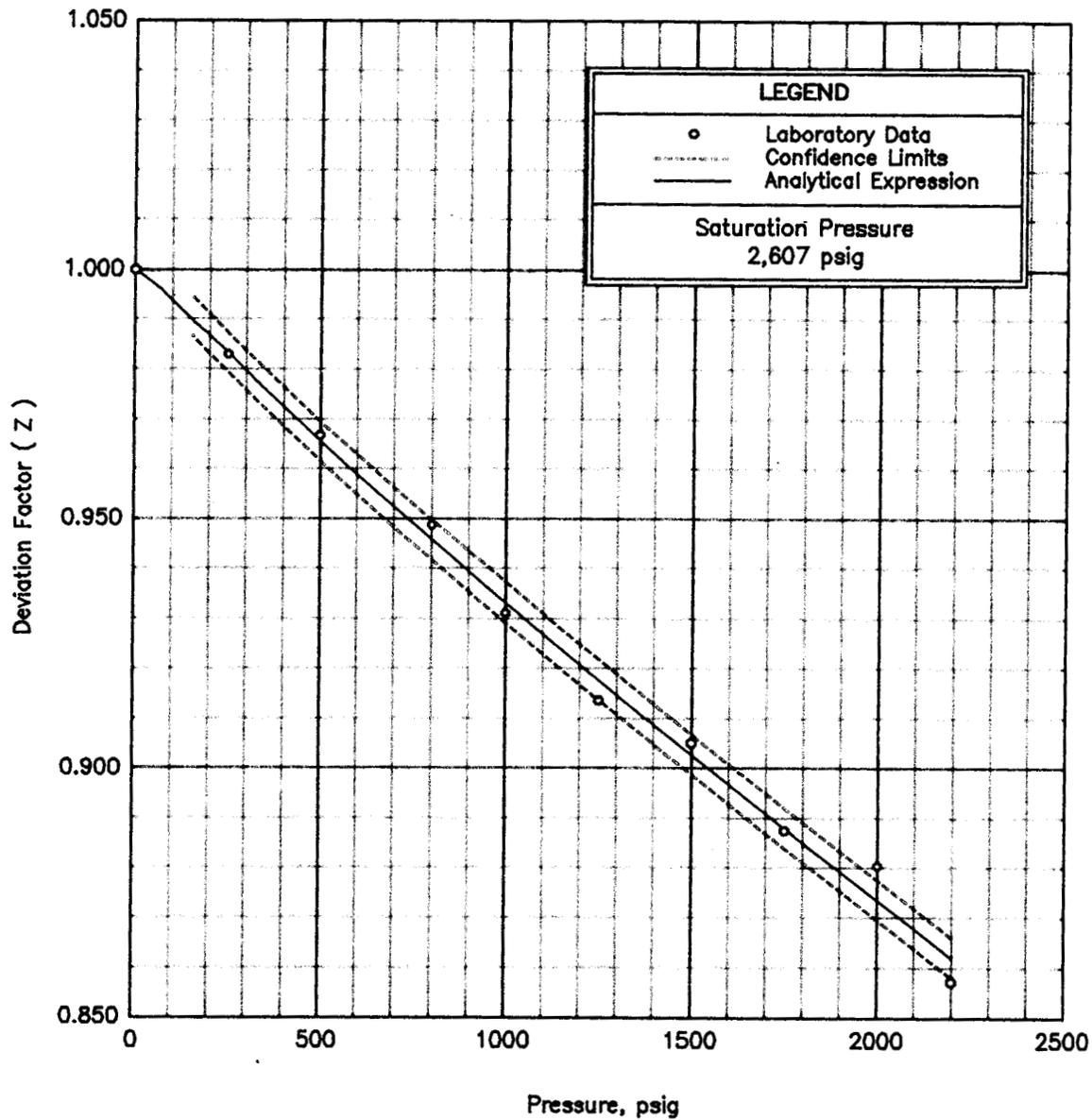
### Differential Vaporization Figure B-4

# Arco Exploration & Production Technology

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## Z-FACTOR ( at 119 °F )



<b>Analytical Expression</b> $1 + -3.979E-05 ( P_i ) + 5.879E-03 ( P_i )^{0.4} + -3.798E-03 ( P_i )^{0.5}$ Note: $P_i$ is defined as pressure, psig	
<b>Statistical Summary</b>	<b>Differential Vaporization</b>  <b>Figure B-5</b>
r squared: 0.994518 Confidence Interval (+/-): 0.004 Confidence: 99 %	

**Arco Exploration & Production Technology**

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**RESERVOIR FLUID VISCOSITY**

(at 119 °F)

Pressure psig	Oil Viscosity cp	Calculated Gas Viscosity* cp	Oil/Gas Viscosity Ratio
5000	5.21		
4000	4.61		
3500	4.33		
3000	4.06		
2700	3.92		
b»2607	3.90		
2200	4.23	0.0168	251
2000	4.41	0.0161	273
1750	4.67	0.0154	304
1500	5.00	0.0147	341
1250	5.42	0.0141	385
1000	5.96	0.0135	441
800	6.50	0.0131	496
500	7.62	0.0126	605
250	9.06	0.0122	743
0	12.8		

\* Gas Viscosity data calculated from correlation of Lee A.L., Gonzalez M.H., and Eakin B.E., "The Viscosity of Natural Gases", Journal of Petroleum Technology, August, 1966, pp. 997-1000.

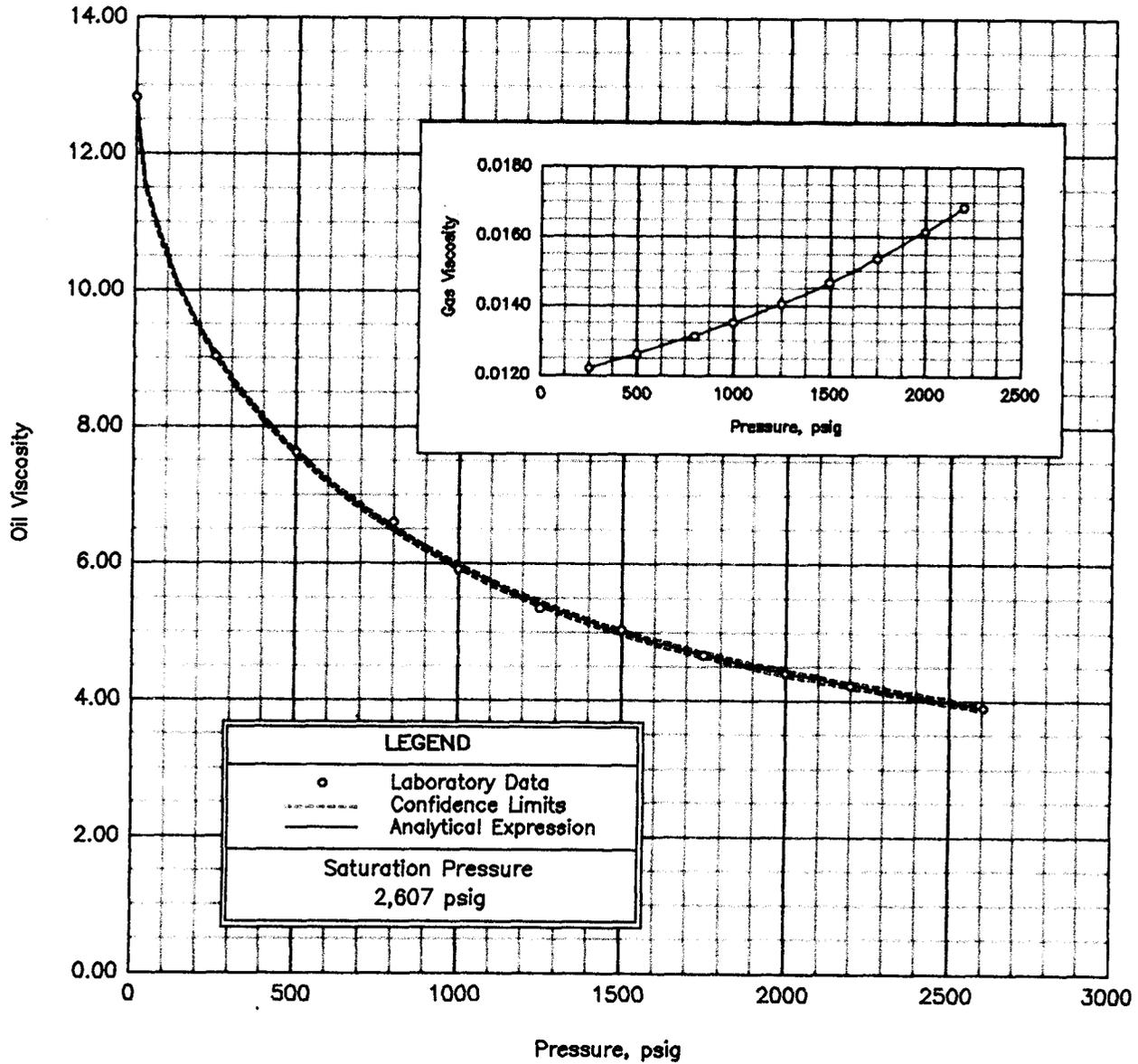
Arco Exploration & Production Technology

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RESERVOIR FLUID VISCOSITIES

( cp at 119 °F )



Analytical Expression (below bubblepoint)

$$1.283 E01 + 4.197E-03 ( P_i ) + -1.754E-01 ( P_i )^{-0.6} + -2.503E-25 ( P_i )^{-7}$$

Note: P<sub>i</sub> is defined as pressure, psig

Statistical Summary

r squared: 0.999761  
 Confidence Interval (+/-): 0.040  
 Confidence: 99 %

Viscosity Analyses

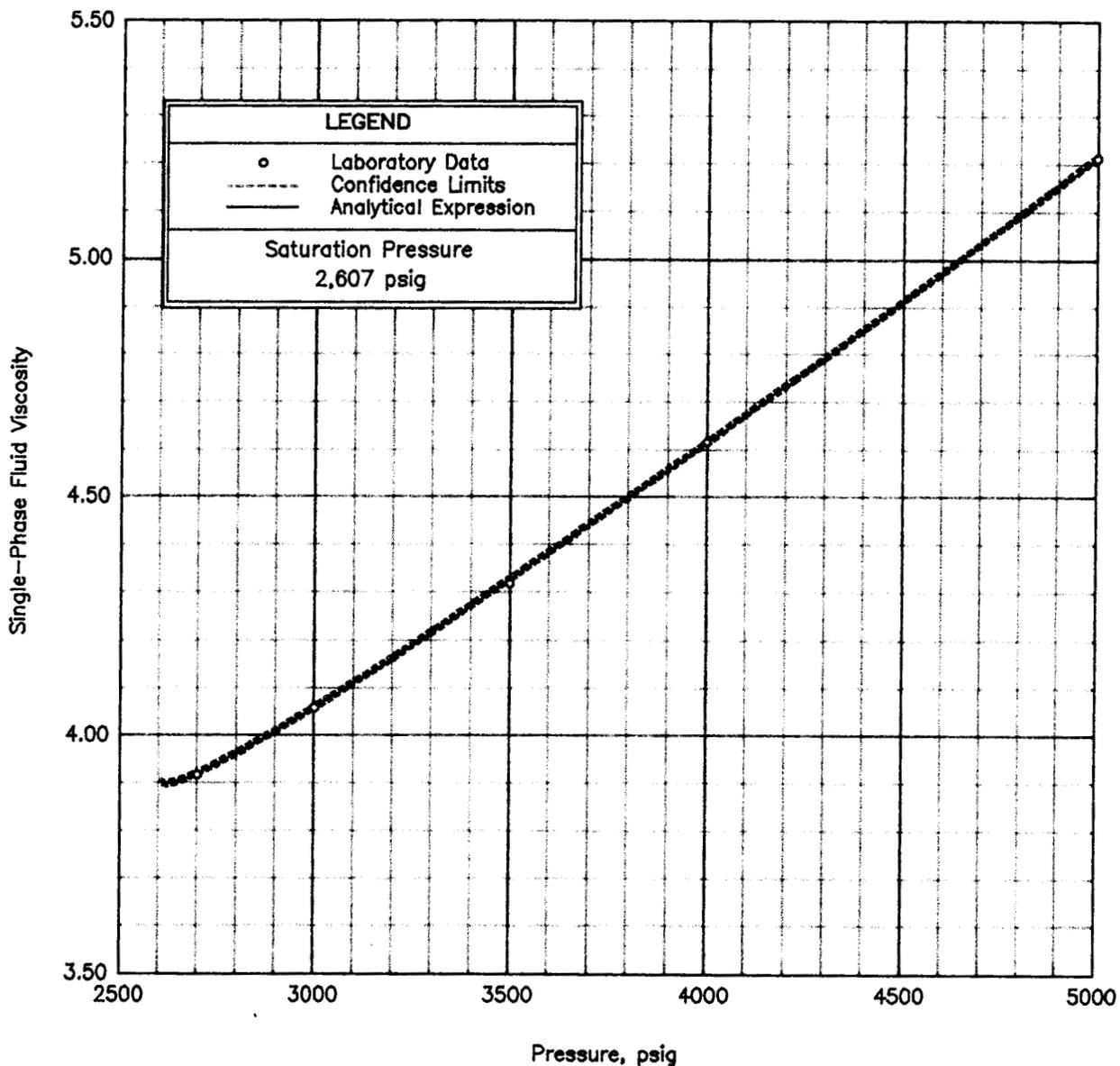
Figure C-1

Arco Exploration & Production Technology

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SINGLE-PHASE VISCOSITY  
( cp at 119 °F )



Analytical Expression

$$3.900E00 + -2.192E-03 ( dP ) + 7.615E-04 ( dP )^{-0.7}$$

Note: dP is defined as | P1 - P2 |, psig

Statistical Summary

r squared: 0.999944  
Confidence Interval (+/-): 0.006  
Confidence: 99 %

Viscosity Analyses

Figure C-2

# Arco Exploration & Production Technology

KUDW No. 2 Well

RFL 930193

## SEPARATOR FLASH ANALYSIS

Flash Conditions		Gas/Oil Ratio (scf/bbl) (A)	Gas/Oil Ratio (scf/STbbl) (B)	Stock Tank Oil Gravity at 60 °F (*API)	Formation Volume Factor Bofb (C)	Separator Volume Factor (D)	Specific Gravity of Flashed Gas (Air=1.000)	Oil Phase Density (gm/cc)
psig	°F							
2607	119							0.8135
100	90	316	325			1.031	0.600 *	0.8654
25	140	11	12			1.050	0.666 *	0.8481
0	60	0	0	27.2*	1.149	1.000	**	0.8907
		Rsfb = 337						
2607	119							0.8135
100	140	312	329			1.052	0.621	0.8480
25	140	8	8			1.052	0.700	0.8469
0	60	1	1	27.2	1.151	1.000	**	0.8907
		Rsfb = 338						
2607	119							0.8135
500	90	240	252			1.050	0.577	0.8559
100	90	54	56			1.034	0.614	0.8620
25	140	15	16			1.050	0.628	0.8468
0	60	0	0	27.5	1.144	1.000	**	0.8891
		Rsfb = 324						

\* Collected and analyzed in the laboratory by gas chromatography.

\*\* Insufficient quantity for measurement.

(A) Cubic Feet of gas at 14.65 psia and 60 °F per Barrel of oil at indicated pressure and temperature.

(B) Cubic Feet of gas at 14.65 psia and 60 °F per Barrel of Stock Tank Oil at 60 °F.

(C) Barrels of saturated oil at 2607 psig and 119 °F per Barrel of Stock Tank Oil at 60 °F.

(D) Barrels of oil at indicated pressure and temperature per Barrel of Stock Tank Oil at 60 °F.

# Arco Exploration & Production Technology

KUDW No. 2 Well

RFL 930193

## SEPARATOR FLASH ANALYSIS OF PREPARED DV OILS

Flash Conditions		Gas/Oil Ratio ( scf/bbl )	Gas/Oil Ratio ( scf/STbbl )	Stock Tank Oil Gravity at 60 °F	Formation Volume Factor Bofb (C)	Separator Volume Factor Factor (D)	Specific Gravity of Flashed Gas ( Air=1.000 )	Oil Phase Density ( gm/cc )
psig	°F	(A)	(B)	(*API)				
2200	119							0.8202
100	90	263	272			1.031	0.602	0.8654
25	140	13	13			1.049	0.725	0.8486
0	60	0	0	27.3	1.131	1.000	**	0.8902
			Rsfb = 285					
1500	119							0.8321
100	90	175	180			1.030	0.611	0.8663
25	140	12	13			1.049	0.746	0.8486
0	60	0	0	27.3	1.101	1.000	**	0.8902
			Rsfb = 193					
800	119							0.8455
100	90	96	99			1.030	0.616	0.8659
25	140	13	13			1.048	0.764	0.8489
0	60	0	0	27.4	1.070	1.000	**	0.8896
			Rsfb = 112					

\*\* Insufficient quantity for measurement.

(A) Cubic Feet of gas at 14.65 psia and 60 °F per Barrel of oil at indicated pressure and temperature.

(B) Cubic Feet of gas at 14.65 psia and 60 °F per Barrel of Stock Tank Oil at 60 °F.

(C) Barrels of gas depleted oil at indicated pressure and 119°F per Barrel of Stock Tank Oil at 60°F.

(D) Barrels of oil at indicated pressure and temperature per Barrel of Stock Tank Oil at 60 °F.

**Arco Exploration & Production Technology**

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**Composition of Primary Separator Gas**

( From Chromatographic Technique )

Component	Mol %	GPM	MW	Liq Dens (gm/cc)
Hydrogen Sulfide	0.00			
Carbon Dioxide	0.33		44.010	.8172
Nitrogen	0.16		28.013	.8086
Methane	95.00		16.043	.2997
Ethane	2.26	.601	30.070	.3558
Propane	1.08	.296	44.097	.5065
iso-Butane	0.46	.150	58.123	.5623
n-Butane	0.25	.078	58.123	.5834
iso-Pentane	0.23	.084	72.150	.6241
n-Pentane	0.07	.025	72.150	.6305
Hexanes	0.08	.031	84.000	.6850
Heptanes	0.04	.017	96.000	.7220
Octanes	0.03	.014	107.00	.7450
Nonanes	0.01	.005	121.00	.7640
Decanes plus	Trace			
<b>Totals .....</b>	<b>100.00</b>	<b>1.301</b>		

**Sampling Conditions**

**100 psig  
90 °F**

**Sample Characteristics**

This is Core Lab sample number 202

Critical Pressure (psia) .....	666.0
Critical Temperature (°R) .....	357.3
Average Molecular Weight .....	17.37
Calculated Gas Gravity (air = 1.000) .....	0.600
<b>Gas Gravity</b>	
Factor, Fg .....	1.2914
Super Compressibility Factor, Fpv at sampling conditions .....	1.0066
Gas Z-Factor at sampling conditions * .....	0.987

**at 14.65 psia and 60 °F**

Heating Value, Btu/scf dry gas Gross .....	1067
---	------

**Properties of Plus Fractions**

Component	Mol %	MW	Liq Dens (gm/cc)	API Gravity
Heptanes plus	0.08	103.3	0.737	60.3

\* From: Standing, M.B., "Volumetric and Phase Behavior of Oil Field Hydrocarbon Systems", SPE (Dallas), 1977, 8th Edition, Appendix II.

**Arco Exploration & Production Technology**  
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**Composition of Secondary Separator Gas**  
( From Chromatographic Technique )

Component	Mol %	GPM	MW	Liq Dens (gm/cc)
Hydrogen Sulfide	0.00			
Carbon Dioxide	0.58		44.010	.8172
Nitrogen	0.05		28.013	.8086
Methane	88.14		16.043	.2997
Ethane	5.47	1.455	30.070	.3558
Propane	2.78	.762	44.097	.5065
iso-Butane	1.12	.364	58.123	.5623
n-Butane	0.63	.198	58.123	.5834
iso-Pentane	0.60	.218	72.150	.6241
n-Pentane	0.14	.050	72.150	.6305
Hexanes	0.22	.085	84.000	.6850
Heptanes	0.12	.050	96.000	.7220
Octanes	0.10	.045	107.00	.7450
Nonanes	0.04	.020	121.00	.7640
Decanes plus	0.01	.006	141.00	.7840
<b>Totals .....</b>	<b>100.00</b>	<b>3.253</b>		

**Sampling Conditions**

**25 psig**  
**140 °F**

**Sample Characteristics**

This is Core Lab sample number 201

Critical Pressure (psia) .....	664.6
Critical Temperature (°R) .....	378.4
Average Molecular Weight .....	19.30
Calculated Gas Gravity (air = 1.000) .....	0.666
Gas Gravity	
Factor, Fg .....	1.2250
Super Compressibility Factor, Fpv	
at sampling conditions .....	1.0020
Gas Z-Factor	
at sampling conditions * .....	0.996

at 14.65 psia and 60 °F

Heating Value, Btu/scf dry gas	
Gross .....	1166

**Properties of Plus Fractions**

Component	Mol %	MW	Liq Dens (gm/cc)	API Gravity
Heptanes plus	0.27	105.4	0.738	60.0
Decanes plus	0.01	141.0	0.784	48.8

\* From: Standing, M.B., "Volumetric and Phase Behavior of Oil Field Hydrocarbon Systems", SPE (Dallas), 1977, 8th Edition, Appendix II.

# Arco Exploration & Production Technology

KUDW No. 2 Well

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## Composition of Stock Tank Oil

( From Chromatographic Technique )

Component	Mol %	Wt %	Density (gm/cc)	MW	Vol %
Hydrogen Sulfide	.00	.00			
Carbon Dioxide	.00	.00			
Nitrogen	.00	.00			
Methane	.00	.00			
Ethane	.00	.00			
Propane	.00	.00			
iso-Butane	.20	.04	.562	58.1	0.06
n-Butane	.20	.04	.583	58.1	0.06
iso-Pentane	.74	.18	.624	72.2	0.26
n-Pentane	.33	.08	.630	72.2	0.12
Hexanes	1.09	.31	.685	84.0	0.40
Heptanes	1.41	.46	.722	96.0	0.57
Octanes	3.12	1.13	.745	107.0	1.35
Nonanes	3.39	1.39	.764	121.0	1.62
Decanes	4.09	1.86	.778	134.0	2.13
Undecanes	3.87	1.93	.789	147.0	2.18
Dodecanes	3.94	2.15	.800	161.0	2.40
Tridecanes	4.99	2.96	.811	175.0	3.25
Tetradecanes	5.25	3.38	.822	190.0	3.66
Pentadecanes	5.93	4.14	.832	206.0	4.44
Hexadecanes	4.72	3.55	.839	222.0	3.77
Heptadecanes	6.02	4.82	.847	237.0	5.09
Octadecanes	3.40	2.89	.852	251.0	3.02
Nonadecanes	3.88	3.46	.857	263.0	3.60
Eicosanes	3.87	3.61	.862	275.0	3.73
Heneicosanes	3.09	3.05	.867	291.0	3.14
Docosanes	2.99	3.09	.872	305.0	3.15
Tricosanes	2.65	2.86	.877	318.0	2.90
Tetracosanes	2.46	2.76	.881	331.0	2.79
Pentacosanes	2.48	2.90	.885	345.0	2.92
Hexacosanes	1.89	2.30	.889	359.0	2.31
Heptacosanes	2.24	2.84	.893	374.0	2.83
Octacosanes	1.69	2.22	.896	388.0	2.21
Nonacosanes	1.98	2.70	.899	402.0	2.67
Triacosanes	1.89	2.66	.902	416.0	2.63
Hentriacontanes	2.09	3.04	.906	430.0	2.99
Dotriacontanes	1.28	1.93	.909	444.0	1.89
Trtriacontanes	1.22	1.89	.912	458.0	1.84
Tetratriacontanes	1.12	1.79	.914	472.0	1.75
Pentatriacontanes	1.09	1.80	.917	486.0	1.75
Hexatriacontanes plus	9.40	23.79	1.030	745.8	20.54
<b>Totals</b>	<b>100.00</b>	<b>100.00</b>			<b>100.00</b>

### Sample Characteristics

This is Core Lab sample number 608

Total Liquid Molecular Weight .....	295.0
Total Liquid Density (gm/cc) .....	0.8907
Total Liquid API Gravity .....	27.2
 Benzene (Wt %) .....	 0.0

### Properties of Heavy Fractions

Plus Fractions	Mol %	Wt %	Density (gm/cc)	°API	MW
Hexanes plus	98.53	99.66	0.892	27.0	298.4
Heptanes plus	97.44	99.35	0.893	26.8	300.8
Decanes plus	89.52	96.37	0.898	25.9	317.6
Undecanes plus	85.43	94.51	0.901	25.4	326.4
Pentadecanes plus	67.38	84.09	0.914	23.2	368.2
Eicosanes plus	43.43	65.23	0.936	19.5	442.9
Pentacosanes plus	28.37	49.86	0.958	16.0	518.3
Triacosanes plus	18.09	36.90	0.984	12.2	601.5
Pentatriacontanes plus	10.49	25.59	1.022	6.9	718.8

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**DIFFERENTIAL VAPORIZATION  
ADJUSTED TO SEPARATOR CONDITIONS\***

Pressure psig	Solution Gas/Oil Ratio Rs (A)	Formation Volume Factor Bo (B)	Gas Formation Volume Factor (C)	Oil Density gm/cc	Oil/Gas Viscosity Ratio
5000	337	1.133		0.8250	
4500	337	1.136		0.8228	
4000	337	1.139		0.8204	
3500	337	1.142		0.8180	
3000	337	1.146		0.8155	
2900	337	1.147		0.8150	
2800	337	1.147		0.8145	
2700	337	1.148		0.8140	
b» 2607	337	1.149		0.8135	
2200	286	1.132	0.00635	0.8204	251.0
2000	261	1.123	0.00707	0.8238	273.0
1750	230	1.112	0.00821	0.8281	304.0
1500	199	1.102	0.00972	0.8326	341.0
1250	167	1.091	0.01184	0.8371	385.0
1000	136	1.080	0.01501	0.8417	441.0
800	110	1.072	0.01894	0.8455	496.0
500	69	1.058	0.03061	0.8514	605.0
250	33	1.046	0.06063	0.8568	743.0
0		1.027		0.8663	

<b>*Separator Conditions</b>	
First Stage	100 psig at 90 °F
Second Stage	25 psig at 140 °F
Stock Tank	0 psig at 60 °F

(A) Cubic Feet of gas at 14.65 psia and 60 °F per Barrel of Stock Tank Oil at 60 °F.

(B) Barrel of oil at indicated pressure and temperature per Barrel of Stock Tank Oil at 60 °F.

(C) Cubic Feet of gas at indicated pressure and temperature per Cubic Feet at 14.65 psia and 60 °F.

# Arco Exploration & Production Technology

KUDW No. 2 Well

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## DIFFERENTIAL VAPORIZATION ADJUSTED TO SEPARATOR CONDITIONS\*

Pressure psig	Solution Gas/Oil Ratio Rs (A)	Formation Volume Factor Bo (B)	Gas Formation Volume Factor (C)	Oil Density gm/cc	Oil/Gas Viscosity Ratio
5000	338	1.135		0.8250	
4500	338	1.138		0.8228	
4000	338	1.141		0.8204	
3500	338	1.145		0.8180	
3000	338	1.148		0.8155	
2900	338	1.149		0.8150	
2800	338	1.150		0.8145	
2700	338	1.150		0.8140	
b> 2607	338	1.151		0.8135	
2200	287	1.134	0.00635	0.8204	251.0
2000	262	1.125	0.00707	0.8238	273.0
1750	231	1.115	0.00821	0.8281	304.0
1500	200	1.104	0.00972	0.8326	341.0
1250	168	1.093	0.01184	0.8371	385.0
1000	136	1.082	0.01501	0.8417	441.0
800	110	1.074	0.01894	0.8455	496.0
500	70	1.060	0.03061	0.8514	605.0
250	33	1.048	0.06063	0.8568	743.0
0		1.029		0.8663	

*Separator Conditions	
First Stage Second Stage Stock Tank	100 psig at 140 °F 25 psig at 140 °F 0 psig at 60 °F

(A) Cubic Feet of gas at 14.65 psia and 60 °F per Barrel of Stock Tank Oil at 60 °F.

(B) Barrel of oil at indicated pressure and temperature per Barrel of Stock Tank Oil at 60 °F.

(C) Cubic Feet of gas at indicated pressure and temperature per Cubic Feet at 14.65 psia and 60 °F.

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**DIFFERENTIAL VAPORIZATION**  
**ADJUSTED TO SEPARATOR CONDITIONS\***

Pressure psig	Solution Gas/Oil Ratio Rs (A)	Formation Volume Factor Bo (B)	Gas Formation Volume Factor (C)	Oil Density gm/cc	Oil/Gas Viscosity Ratio
5000	324	1.128		0.8250	
4500	324	1.131		0.8228	
4000	324	1.134		0.8204	
3500	324	1.137		0.8180	
3000	324	1.141		0.8155	
2900	324	1.141		0.8150	
2800	324	1.142		0.8145	
2700	324	1.143		0.8140	
b» 2607	324	1.144		0.8135	
2200	274	1.126	0.00635	0.8204	251.0
2000	249	1.118	0.00707	0.8238	273.0
1750	218	1.107	0.00821	0.8281	304.0
1500	187	1.097	0.00972	0.8326	341.0
1250	156	1.086	0.01184	0.8371	385.0
1000	124	1.075	0.01501	0.8417	441.0
800	98	1.067	0.01894	0.8455	496.0
500	58	1.053	0.03061	0.8514	605.0
250	22	1.041	0.06063	0.8568	743.0
0		1.022		0.8663	

<b>*Separator Conditions</b>	
First Stage	500 psig at 90 °F
Second Stage	100 psig at 90 °F
Third Stage	25 psig at 140 °F
Stock Tank	0 psig at 60 °F

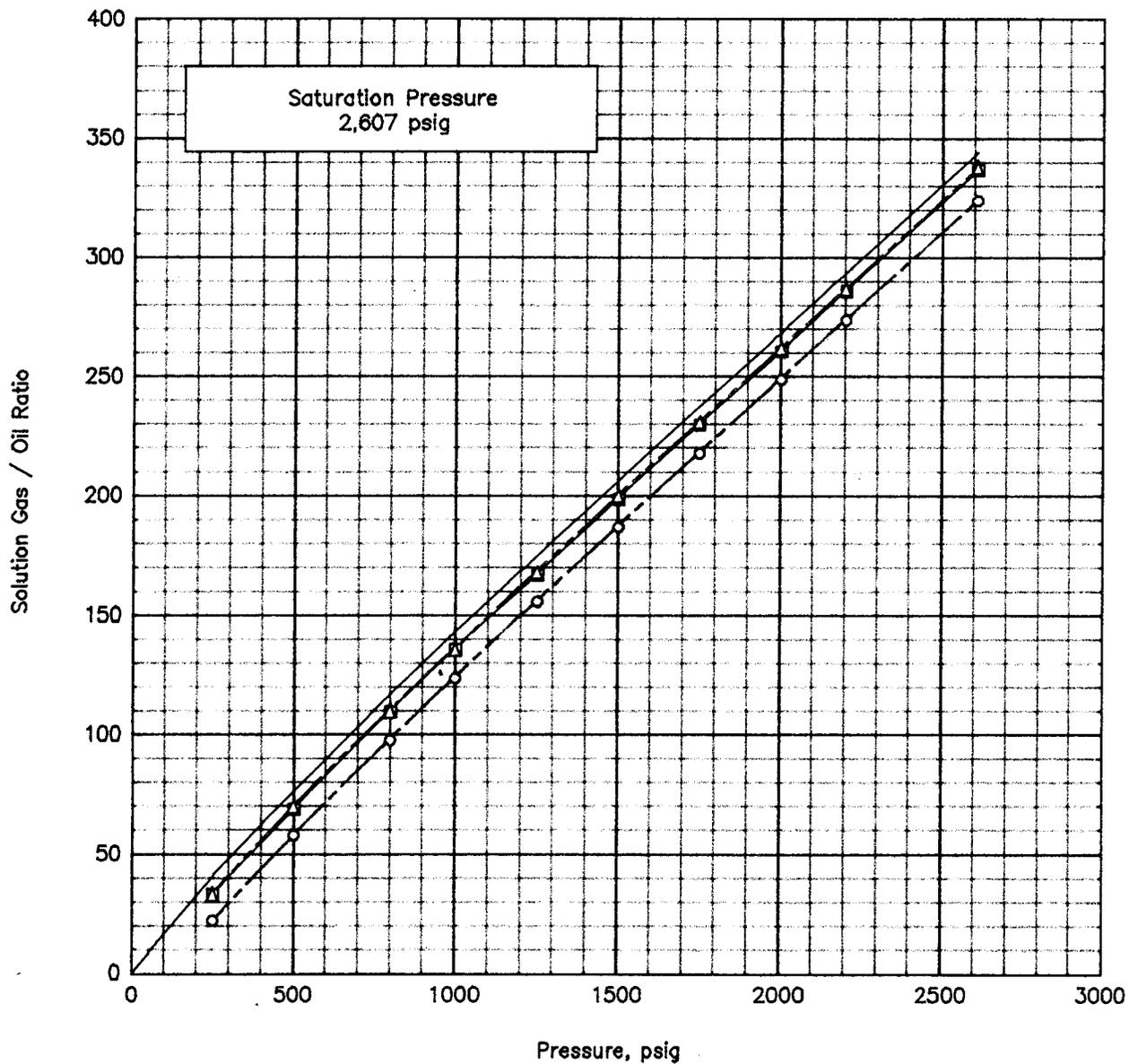
- (A) Cubic Feet of gas at 14.65 psia and 60 °F per Barrel of Stock Tank Oil at 60 °F.  
 (B) Barrel of oil at indicated pressure and temperature per Barrel of Stock Tank Oil at 60 °F.  
 (C) Cubic Feet of gas at indicated pressure and temperature per Cubic Feet at 14.65 psia and 60 °F.

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KUDW No. 2 Well

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SOLUTION GAS/OIL RATIO  
( scf/STbbl )

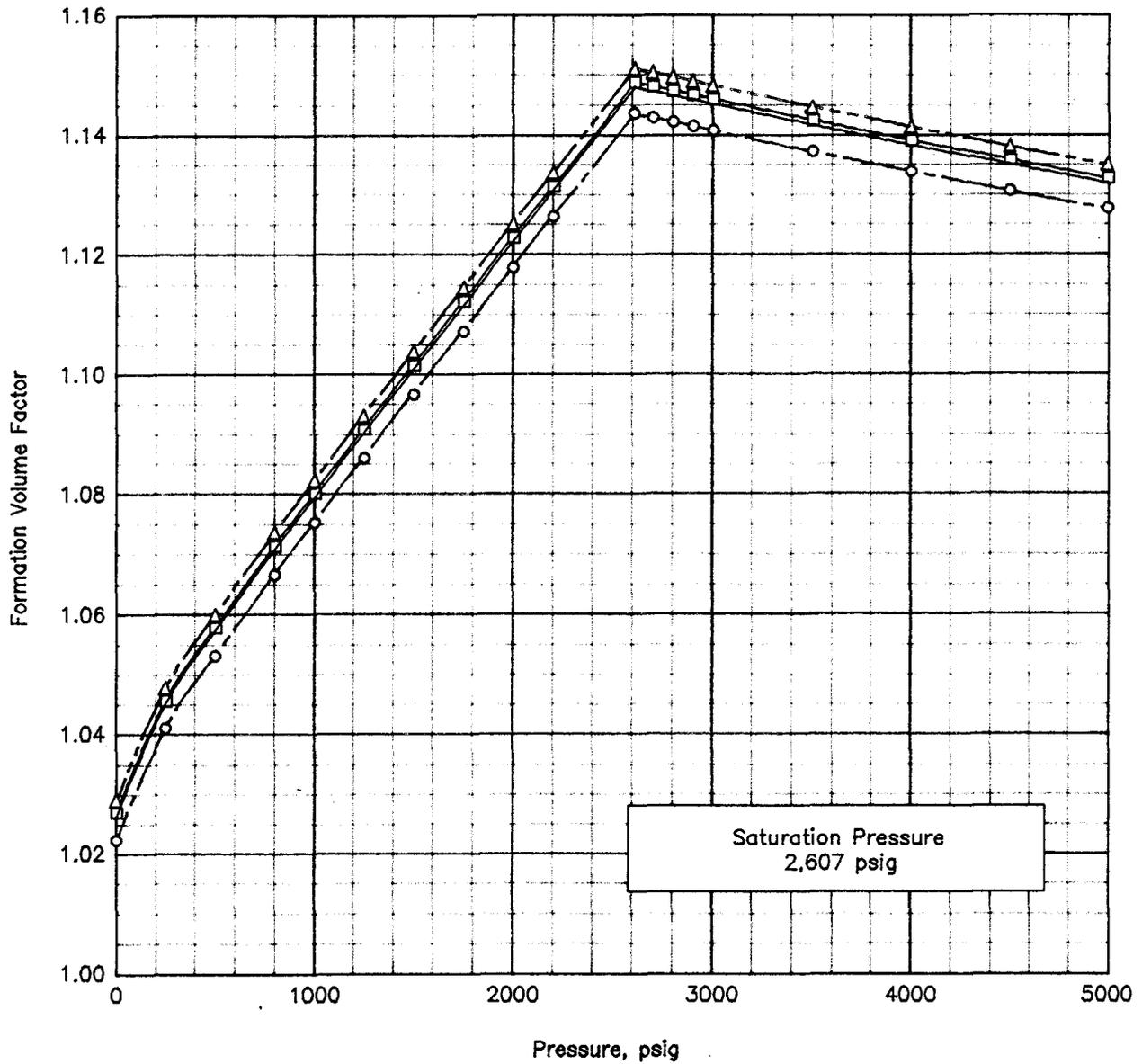


LEGEND	
—	Differential Vaporization
□	100 psig at 90 °F
△	100 psig at 140 °F
○	500 psig at 90 °F

DV Adjusted to Separator  
Figure D-1

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FORMATION VOLUME FACTOR



LEGEND	
—	Differential Vaporization
□	100 psig at 90 °F
△	100 psig at 140 °F
○	500 psig at 90 °F

DV Adjusted to Separator  
 Figure D-2

**Appendix**  
**Nomenclature and Equations**

## PRESSURE-VOLUME RELATIONS

### Nomenclature and Equations

$P_b$	=	Bubblepoint Pressure
$X_d$	=	Dimensionless Pressure ( $P_i / P_b$ )
$dP$	=	Pressure Difference ( $P_i - P_b$ )
$Y_f$	=	Y-Function (dimensionless compressibility)
$RV$	=	PV Relative Volume
$C_{sp}$	=	Average Single-Phase Compressibility of Reservoir Fluid

For Relative Volume below bubblepoint pressure:

$$RV_i = ((P_b - P_i) / P_i) / Y_f$$

For Average Single-Phase Compressibility above bubblepoint pressure:

$$C_{sp} = (RV_i - RV_{i-1}) / [RV_i(P_{i-1} - P_i)]$$

## DIFFERENTIAL VAPORIZATION

### Nomenclature and Equations

$P_b$	=	Bubblepoint Pressure
$P_{base}$	=	Base Pressure
$T_{base}$	=	Base Temperature
$T_{res}$	=	Reservoir Temperature
$X_d$	=	Dimensionless Pressure ( $P_i / P_b$ )
$dP$	=	Pressure Difference ( $P_i - P_b$ )
$RV$	=	Relative Volume from Pressure-Volume Relations
$Dens$	=	Single-Phase Oil Density
$Dens_b$	=	Oil Density at Bubblepoint Pressure
$ROV$	=	Relative Oil Volume
$ROV_b$	=	Relative Oil Volume at Bubblepoint Pressure
$B_g$	=	Gas Formation Volume Factor

For Oil Density above bubblepoint pressure:

$$Dens_i = Dens_b / RV_i$$

For Relative Oil Volume above bubblepoint pressure:

$$ROV_i = ROV_b * RV_i$$

For Gas Formation Volume Factor below bubblepoint pressure:

$$B_g = P_{base} * Z_i * T_{res} / (P_i * T_{base})$$

## DIFFERENTIAL VAPORIZATION DATA ADJUSTED TO SURFACE CONDITIONS

### Nomenclature and Equations

$P_b$	=	Bubblepoint Pressure
$B_o$	=	Oil Formation Volume Factor
$B_{ofb}$	=	Formation Volume Factor from field conditions or optimum separator flash test
$B_{od}$	=	Relative Oil Volume from differential vaporization test
$B_{odb}$	=	Value of $B_{od}$ at bubblepoint pressure
$RV$	=	Relative Volume from Pressure-Volume relations

For  $B_o$  above bubblepoint pressure:

$$B_o = RV * B_{ofb}$$

For  $B_o$  below bubblepoint pressure:

$$B_o = (B_{od}) * (B_{ofb} / B_{odb})$$

$R_s$	=	Gas in solution
$R_{sfb}$	=	Sum of separator gas and the stock tank gas from field conditions (or optimum) separator flash test
$R_{sd}$	=	Gas in solution from the differential vaporization test
$R_{sdb}$	=	$R_{sd}$ at bubblepoint pressure

$$R_s = R_{sfb} - [ (R_{sdb} - R_{sd}) * (B_{ofb} / B_{odb}) ]$$