

CORE LABORATORIES, INC.
Petroleum Reservoir Engineering
DALLAS, TEXAS 75207

RESERVOIR FLUID DIVISION

Good Oil Company
P. O. Box 100
Oil City, Texas 10010

Attention: Mr. John L. Jones

Subject: Reservoir Fluid Study
Oil Well No. 4
Productive Field
Samson County, Texas

Gentlemen:

Wireline (cased hole) "BHS"

Two subsurface fluid samples were collected from the subject well and forwarded to our Dallas laboratory for a reservoir fluid study. Room temperature bubble points of these samples were measured and found to be 1118 psig and 1110 psig for Sample No. 1 and Sample No. 2, respectively. Subsurface Sample No. 1 was selected for the study. The results of this study are reported herein.

Check for leakage

The bubble point pressure was found to be 1270 psig at the reservoir temperature of 114°F. During differential pressure depletion at 114°F., the reservoir fluid evolved 425 standard cubic feet of vapor per barrel of residual oil. The associated formation volume factor was found to be 1.221 barrels of fluid per barrel of residual liquid.

DLE

Body, b

R_{sd, b}

The viscosity of the fluid was measured from above reservoir pressure to atmospheric pressure. This viscosity was found to vary from a minimum of 0.624 centipoise at bubble point pressure to a maximum of 1.241 centipoises at atmospheric pressure. The gravity of this residual oil was found to be 44.0° API at 60°F.

DLE_{oil}

oil

Separator tests were made at 130°F. and at pressures ranging from 30 to 200 psig. These separator tests indicate an optimum separator

T_{sp1} why

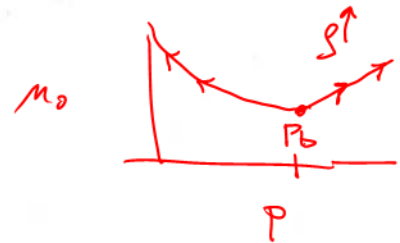
P_{sp1}

All Two-Stage Separator tests

optimal:



$\mu_o \propto f_o^4$



Good Oil Company
Oil Well No. 4

$$\gamma_{API} = \frac{141.5}{\gamma_o} - 131.5$$

Page Two

(Psp)_{optimal}

max V_o *min* $(\gamma_o) S_o$ *max* γ_{API} ρ_{API}

pressure of 100 to 125 psig result in near maximum recovery and maximum stock tank oil gravity. The vapors from the separator tests were collected and analyzed by chromatographic techniques. The results of these analyses are reported on pages seven through ten.

BHS

Z_i

The reservoir fluid was analyzed by low temperature fractional distillation. The results are presented on page eleven of this report.

(y_i)₁ *Gas Processing*
C₃ C₄ C₅ as
NGHS
+ Gas Chromatography

It has been a pleasure to perform this study for you. Should you have any questions regarding these data or if we may be of further assistance, please feel free to contact us.

Very truly yours,

Core Laboratories, Inc.
Reservoir Fluid Analysis

Manager

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Company Good Oil Company Date Sampled December 1 1975
 Well Oil Well No. 4 County Samson
 Field Productive State Texas

FORMATION CHARACTERISTICS

Formation Name Cretaceous
 Date First Well Completed December 18 1972
 Original Reservoir Pressure 3015 PSIG @ 5994 Ft. KB
 Original Produced Gas-Oil Ratio 450 SCF/Bbl
 Production Rate of oil 300 sep. Bbl/Day } Production data prior to or during sampling
 Separator Pressure and Temperature 60 PSIG, 130 °F. } STB? Psp1 Lsp1
 Oil Gravity at 60° F 43.2 °API
 Datum of what? 5350 Ft. Subsea
 Original Gas Cap No } If yes PR ~ Pb close

WELL CHARACTERISTICS

Elevation 640 Ft. KB
 Total Depth 6200 Ft. KB
 Producing Interval 5989-5999 Ft. KB
 Tubing Size and Depth 2-7/8 O. D. In. to 5980 Ft. KB
 Productivity Index 1.5 Bbl/D/PSI @ 300 Bbl/Day
 Last Reservoir Pressure 2990 PSIG @ 5994 Ft. KB
 Date December 1 1975
 Reservoir Temperature 114 °F. @ 5994 Ft. KB
 Status of Well Shut in 72 hours } during sampling
 Pressure Gauge Amerada
 Normal Production Rate 300 STB or sep. Bbl/Day
 Gas-Oil Ratio 450 SCF/Bbl
 Separator Pressure and Temperature 60 PSIG, 130 °F.
 Base Pressure 14.65 PSIA
 Well Making Water None % Cut

SAMPLING CONDITIONS

Sampled at 4950 ⁹⁰ ₉₀₊₉₀ Ft. KB
 Status of Well Shut in 72 hours.
 Gas-Oil Ratio _____ SCF/Bbl
 Separator Pressure and Temperature _____ PSIG, _____ °F.
 Tubing Pressure 1210 PSIG
 Casing Pressure Packer PSIG
 Core Laboratories Engineer PLM
 Type Sampler Wofford

REMARKS:

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 Well Oil Well No. 4

CCE Test results

VOLUMETRIC DATA OF Reservoir Fluid SAMPLE

1. Saturation pressure (bubble-point pressure) P_b T_R
 1270 PSIG @ 114 °F.

2. Thermal expansion of saturated oil @ 5000 PSI = $\frac{V @ 114 \text{ °F}}{V @ 74 \text{ °F}} = 1.02067$

3. Compressibility of saturated oil @ reservoir temperature: Vol/Vol/PSI:

$C = -\frac{1}{V} \left(\frac{dV}{dp} \right)$

From 5000 PSI to 4000 PSI = $(7.27 \times 10^{-6}) @ 4500$
 From 4000 PSI to 2000 PSI = $8.30 \times 10^{-6} @ 3000$
 From 2000 PSI to 1270 PSI = $9.68 \times 10^{-6} @ \frac{1270+200}{2}$

4. Specific volume at saturation pressure: ft³/lb 0.02211 @ 114 °F.

$v = \frac{1}{\rho} @ P_b$

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Well Oil Well No. 4

CCE & DLE

Reservoir Fluid SAMPLE TABULAR DATA

PRESSURE PSI GAUGE	PRESSURE-VOLUME RELATION @ 114 °F. RELATIVE VOLUME OF OIL AND GAS, V/V _{BAT.}	VISCOSITY OF OIL @ 114 °F. CENTIPOISES	DIFFERENTIAL LIBERATION @ 114 °F.		
			GAS/OIL RATIO LIBERATED PER BARREL OF RESIDUAL OIL	GAS/OIL RATIO IN SOLUTION PER BARREL OF RESIDUAL OIL	RELATIVE OIL VOLUME, V/V _R
	<i>CCF</i>	<i>CCE/DLE_m</i>			
5000	0.9694	0.851			1.183
4500	0.9727				1.187
4000	0.9765	0.792			1.192
3500	0.9803	0.761			1.197
3000	0.9843	0.730			1.201
2500	0.9885	0.702			1.207
2000	0.9929	0.669			1.212
1700	0.9958				1.215
1600	0.9967				1.217
1500	0.9976	0.638			1.218
1400	0.9986				1.219
1300	0.9997				1.220
1270	1.0000	0.624	0	425	1.221
1263	1.0023				
1257	1.0044				
1251	1.0064				
1226	1.0156				
1177	1.0365				
1112	1.0680				
1100	×	0.666	46	379	1.201
1037	1.1098				
950	×	0.709	87	338	1.185
943	1.1729				
844	1.2569				
800		0.759	129	296	1.167
738	1.3832				
650		0.816	170	255	1.151
622	1.5725				
500		0.883	211	214	1.136
498	1.8767				
400	2.2756				
350		0.959	254	171	1.118
304	2.9085				

v = Volume at given pressure
 V_{BAT.} = Volume at saturation pressure and the specified temperature.
 V_R = Residual oil volume at 14.65 PSI absolute and 60° F.

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Well Oil Well No. 4

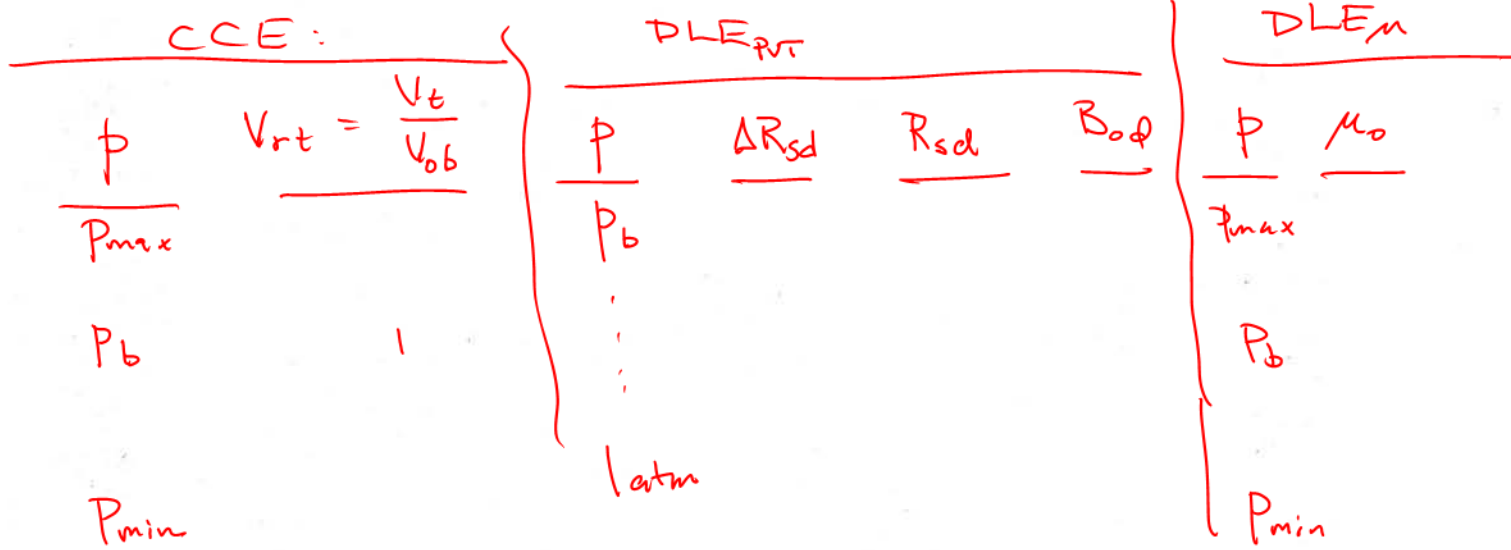
Reservoir Fluid SAMPLE TABULAR DATA

PRESSURE PSI GAUGE	PRESSURE-VOLUME RELATION @ 114 °F.. RELATIVE VOLUME OF OIL AND GAS, V/V _{BAT} .	VISCOSITY OF OIL @ 114 °F.. CENTIPOISES	DIFFERENTIAL LIBERATION @ 114 °F.		
			GAS/OIL RATIO LIBERATED PER BARREL OF RESIDUAL OIL	GAS/OIL RATIO IN SOLUTION PER BARREL OF RESIDUAL OIL	RELATIVE OIL VOLUME, V/V _R

222	3.9336		$\Delta R_{sd} = R_{sd,b} - R_{sd}$	R_{sd}	B_{od}	
200				298	127	1.100
108				333	92	1.084
60				352	73	1.074
<u>0</u>			<u>1.241</u>	<u>425</u>	<u>0</u>	<u>1.028</u> @ 114°F
						@ 60°F. = 1.000 cooled to T_{sc}

Gravity of residual oil = 44.0° API @ 60°F.

Exercise: break the table into three tables



- v = Volume at given pressure
- V_{BAT} = Volume at saturation pressure and the specified temperature.
- V_R = Residual oil volume at 14.65 PSI absolute and 60° F.

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Well Oil Well No. 4

Differential Pressure Depletion at 114° F.

+ DLE_{PVT} table

You Calculate
 L-G

<u>Pressure PSIG</u>	<u>Oil Density Gms/Cc</u>	<u>Gas Gravity</u>	<u>Deviation Factor Z</u>	<u>S_g</u>	<u>M_g</u>
1270	0.7245	0.652	0.893		
1100	0.7311	0.658	0.903		
950	0.7357	0.663	0.915		
800	0.7419	0.673	0.931		
650	0.7469	0.691	0.943		
500	0.7517	0.721	0.960		
350	0.7576	0.785	0.974		
200	0.7634	0.908	0.988		
108	0.7679	1.031			
60	0.7715	1.447			
0	0.7838				

removed gases

$$S_g = \frac{p \cdot 28.97 \gamma_g}{RT_B Z_g} @ p, T_B$$

SEPARATOR TESTS OF Reservoir Fluid SAMPLE

SEPARATOR PRESSURE, PSI GAUGE	SEPARATOR TEMPERATURE, ° F.	SEPARATOR GAS/OIL RATIO See Foot Note (1)	STOCK TANK GAS/OIL RATIO See Foot Note (1)	STOCK TANK GRAVITY, ° API @ 60° F.	SHRINKAGE FACTOR, V _R /V _{SAT.} See Foot Note (2)	FORMATION VOLUME FACTOR, V _{SAT.} /V _R See Foot Note (3)	SPECIFIC GRAVITY OF FLASHED GAS
<u>P_{sp1}</u> 30	<u>T_{sp1}</u> 130	<u>V_{g,sp1} = 448</u> (473 - 25)		43.1	0.7877	1.270	0.952 (1)
60	130	447	36	43.4	0.7963	1.256	0.918 (2)
100	130	<u>415</u>	<u>56</u>	<u>43.5</u>	<u>0.8043</u>	<u>1.243</u>	<u>0.876</u> (3)
200	130	349	126	43.3	0.7954	1.257	0.759 (4)

2nd Stage: 1 atm @ 60°F

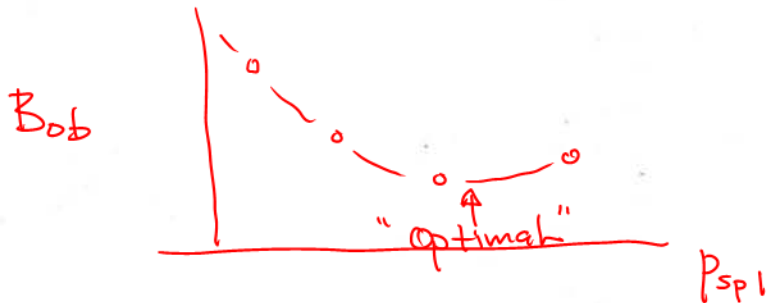
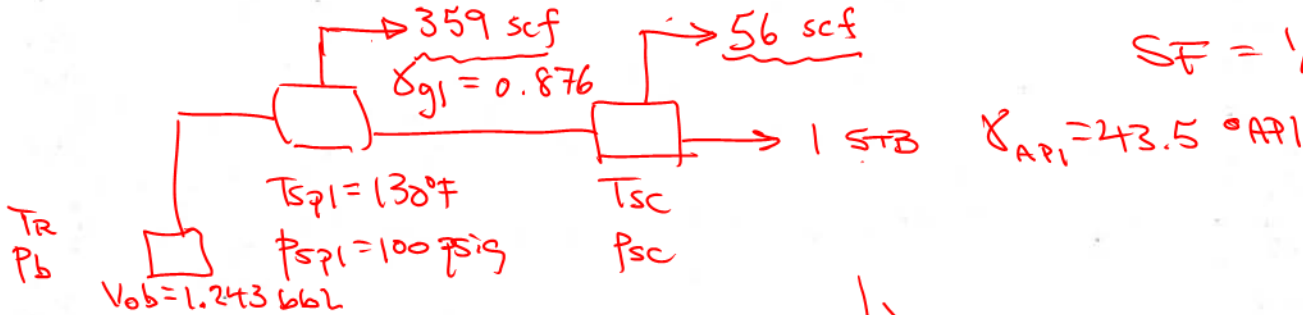
4 independent 2-stage separator tests

Sep. Test #3

+ 56 = 415

$B_{ob} = \frac{V_{ob}}{V_o} = \frac{1.243}{1.0}$

$SF = 1/B_{ob} = 0.8043$



- (1) Separator and Stock Tank Gas/Oil Ratio in cubic feet of gas @ 60° F. and 14.65 PSI absolute per barrel of stock tank oil @ 60° F.
- (2) Shrinkage Factor: V_R/V_{SAT.} is barrels of stock tank oil @ 60° F. per barrel of saturated oil @ 1270 PSI gauge and 114 ° F.
- (3) Formation Volume Factor: V_{SAT.}/V_R is barrels of saturated oil @ 1270 PSI gauge and 114 ° F. per barrel of stock tank oil @ 60° F.

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Company Good Oil Company Formation Cretaceous

Well Oil Well No. 4 County Samson

Field Productive State Texas

[(Y) stage 1] ①

HYDROCARBON ANALYSIS OF Primary Separator GAS SAMPLE

COMPONENT	MOL PER CENT	GPM
Carbon Dioxide	1.54	
Nitrogen	0.14	
Methane	61.48	
Ethane	15.16	3.807
Propane	10.76	2.944
iso-Butane	2.43	0.790
n-Butane	3.69	1.157
iso-Pentane	1.21	0.440
n-Pentane	0.94	0.339
Hexanes...	0.86	0.349
Heptanes plus	1.79	0.808
	100.00	10.634

Gallons per Mscf
 42 gal / STB

NGLS
 Gas "Loss"

"easy" NGL
 STB

Calculated gas gravity (air = 1.000) = 0.952

Calculated gross heating value = 1582 BTU
 per cubic foot of dry gas at 14.65 psia at 60° F.

Collected at 30 psig and 130 ° F. in the laboratory.

Psig

How many STB
 of NGL come
 in addition ± STB

$$V_{g, sp} = 0.448 \text{ Mscf}$$

$$V_{NGL} = \frac{(10.634 - 3.807) \text{ gal}}{\text{Mscf}} \times \frac{0.448 \text{ Mscf}}{42 \text{ gal}} = 0.073 \text{ STB}$$

Total Stock Tank Liquids
 STO + NGLS = 1.073 STB

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Company Good Oil Company Formation Cretaceous
 Well Oil Well No. 4 County Samson
 Field Productive State Texas

HYDROCARBON ANALYSIS OF Primary Separator GAS SAMPLE

COMPONENT	MOL PER CENT	G P M
Carbon Dioxide	1.59	
Nitrogen	0.16	
Methane	62.65	
Ethane	15.65	3.930
Propane	10.74	2.939
iso-Butane	2.26	0.735
n-Butane	3.31	1.037
iso-Pentane	1.00	0.364
n-Pentane	0.75	0.270
Hexanes	0.61	0.247
Heptanes plus	1.28	0.578
	100.00	10.100

Calculated gas gravity (air = 1.000) = 0.918

Calculated gross heating value = 1528 BTU
 per cubic foot of dry gas at 14.65 psia at 60° F.

Collected at 60 psig and 130 ° F. in the laboratory.

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DALLAS, TEXAS

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Company Good Oil Company Formation Cretaceous
 Well Oil Well No. 4 County Samson
 Field Productive State Texas

HYDROCARBON ANALYSIS OF Primary Separator GAS SAMPLE

COMPONENT	MOL PER CENT	G P M
Carbon Dioxide	1.67	
Nitrogen	0.13	
Methane	64.73	
Ethane	16.08	4.038
Propane	10.10	2.763
iso-Butane	1.96	0.637
n-Butane	2.75	0.862
iso-Pentane	0.77	0.280
n-Pentane	0.57	0.205
Hexanes	0.41	0.166
Heptanes plus	0.83	0.375
	100.00	9.326

Calculated gas gravity (air = 1.000) = 0.876

Calculated gross heating value = 1461 BTU
 per cubic foot of dry gas at 14.65 psia at 60° F.

Collected at 100 psig and 130 ° F. in the laboratory.

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Company Good Oil Company Formation Cretaceous
 Well Oil Well No. 4 County Samson
 Field Productive State Texas

HYDROCARBON ANALYSIS OF Primary Separator GAS SAMPLE

COMPONENT	MOL PER CENT	G P M
Carbon Dioxide	1.68	
Nitrogen	0.16	
Methane	74.73	
Ethane	13.52	3.395
Propane	6.37	1.743
iso-Butane	1.05	0.342
n-Butane	1.37	0.429
iso-Pentane	0.37	0.135
n-Pentane	0.27	0.097
Hexanes	0.16	0.065
Heptanes plus	0.32	0.145
	100.00	6.351

Calculated gas gravity (air = 1.000) = 0.759

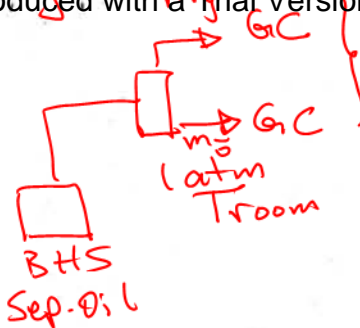
Calculated gross heating value = 1280 BTU
 per cubic foot of dry gas at 14.65 psia at 60° F.

Collected at 200 psig and 130 ° F. in the laboratory.

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Company Good Oil Company Formation Cretaceous
 Well Oil Well No. 4 County Samson
 Field Productive State Texas

HYDROCARBON ANALYSIS OF Reservoir Fluid SAMPLE

COMPONENT	MOL PER CENT	WEIGHT PER CENT	DENSITY @ 60° F. GRAMS PER CUBIC CENTIMETER	° API @ 60° F.	MOLECULAR WEIGHT
	Z_i	W_i			
	n_i	m_i			
Carbon Dioxide	0.66	0.28			
Nitrogen	0.12	0.03			
Methane	25.43	3.85			
Ethane	6.47	1.84			
Propane	5.39	2.24			
iso-Butane	1.78	0.98			
n-Butane	2.58	1.41			
iso-Pentane	1.41	0.96			
n-Pentane	1.18	0.81			
Hexanes	3.14	2.54			
Heptanes plus	51.84	85.06	0.8211	40.7	174 ± 2% - 10%
	100.00	100.00			

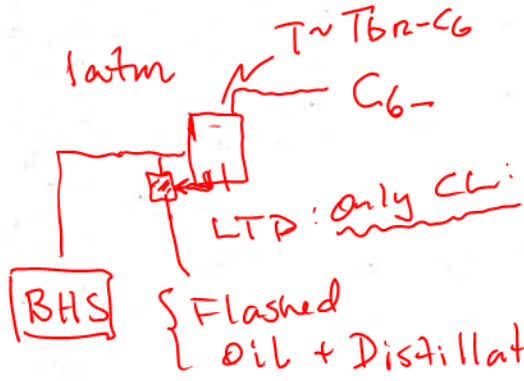
$m_{gi} = m_g \cdot w_{gi}$

LTD "gas" => G.C. $m_g = m_{C6-}$
 w_{gi}

weigh this, $m_0 = m_{C7+}$

$n_i = m_i / M_i$
 $n_i = \frac{n_i}{n_{C6-} + n_{C7+}}$
 $Z_i = \frac{n_i}{n}$

everything all compounds boiling > T_{b,n-C6}



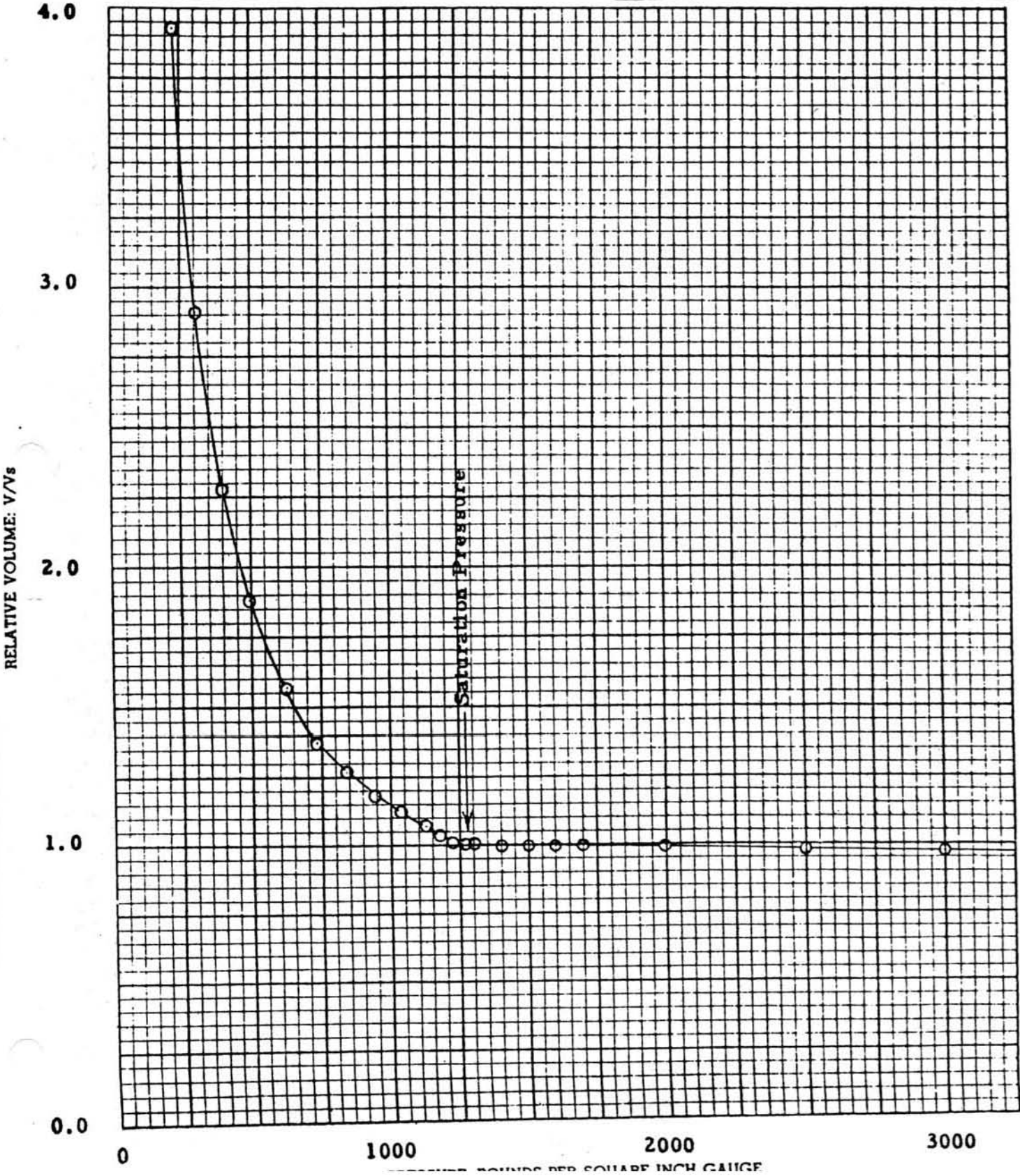
C_{7+}
 M_{7+} ρ_{7+}

Core Laboratories, Inc.
 Reservoir Fluid Analysis

Manager

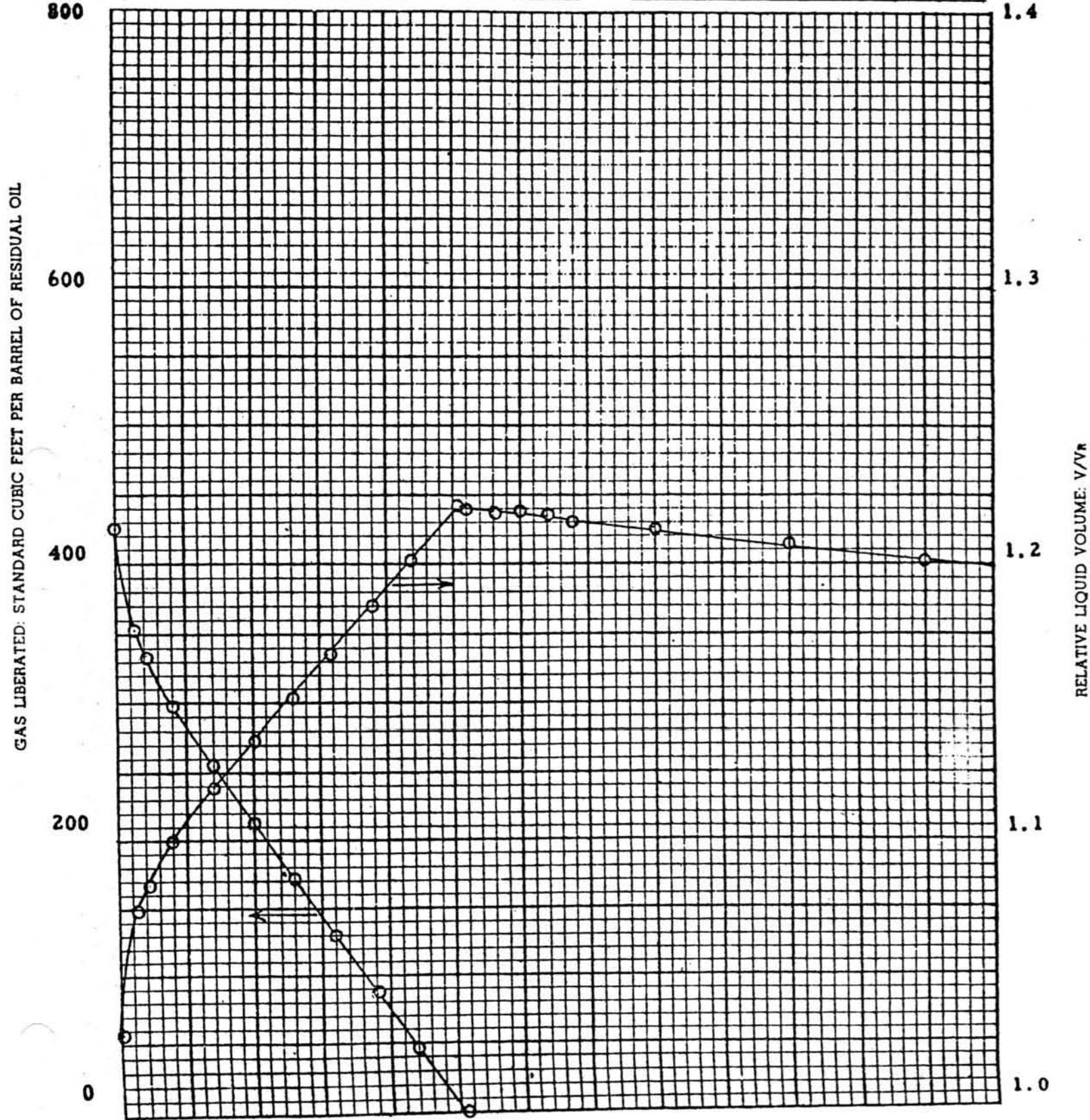
PRESSURE-VOLUME RELATIONS OF RESERVOIR FLUID

Company	Good Oil Company	Formation	Cretaceous
Well	Oil Well No. 4	County	Samson
Field	Productive	State	Texas



DIFFERENTIAL VAPORIZATION OF RESERVOIR FLUID

Company	Good Oil Company	Formation	Cretaceous
Well	Oil Well No. 4	County	Samsom
Field	Productive	State	Texas



PRESSURE IN POUNDS PER SQUARE INCH GAUGE

VISCOSITY OF RESERVOIR FLUID

Company Good Oil Company Formation Cretaceous
Well Oil Well No. 4 County Samson
Field Productive State Texas

