

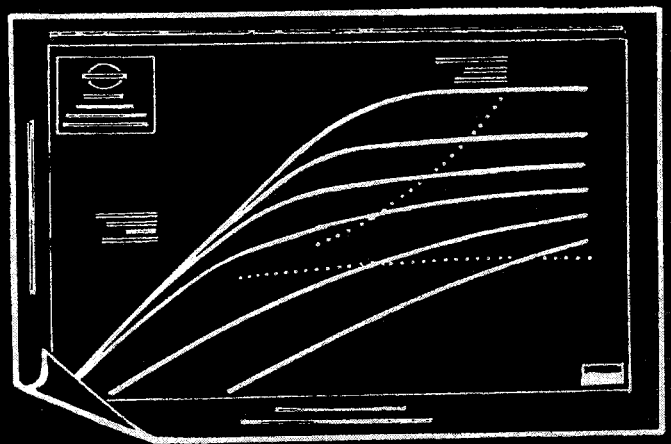
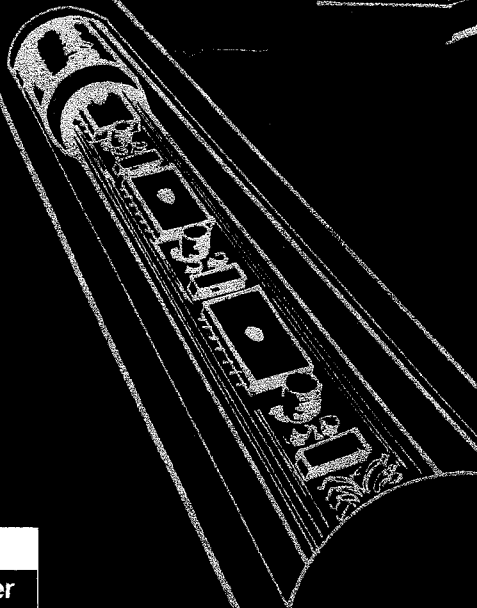
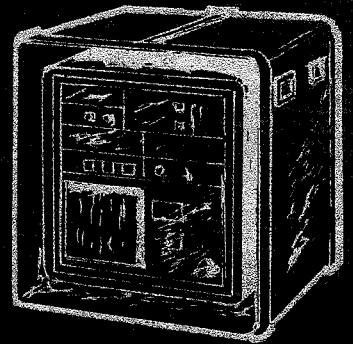
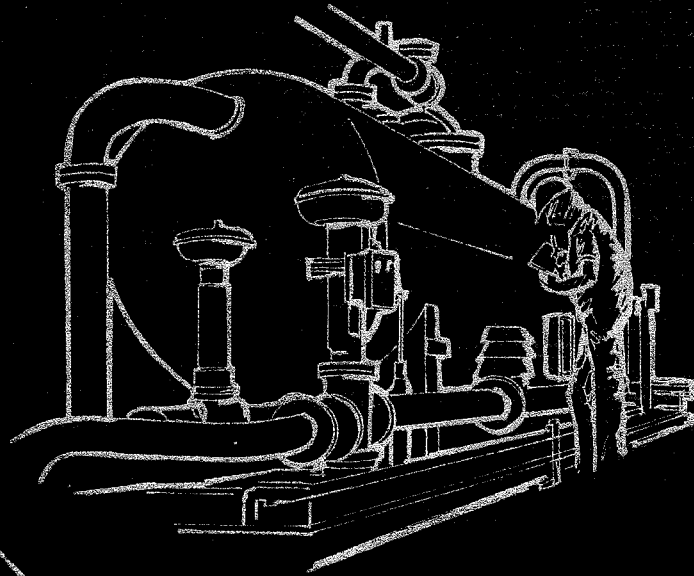
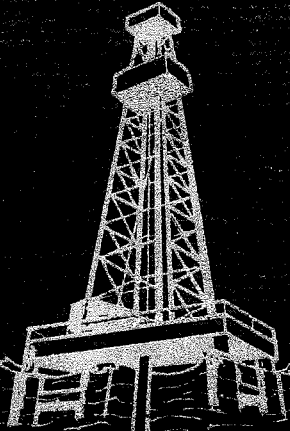
BP027323

FLOPETROL

P.V.T. STUDY REPORT

Client: AMOCO NORWAY OIL COMPANY
Field: TOR FORM. Well: 2/11-6(ST1)DST2
Zone: 3713-3735MD Samp. date: 02/18tn/82

Report #: 82/L/041 Date: APRIL 1982



FLOPETROL
Schlumberger

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HEADQUARTERS LABORATORY

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SUMMARY AND MAIN RESULTS

The present report gives the experimental results of the P.V.T. study carried out on bottom hole sample(s) from well 2/11-6 (ST1) DST2

The initial reservoir conditions are :

- Pi : 6850 psig
- T : 220 F

Bubble point pressure determined on sample which was selected for complete P.V.T. study is :

- Pb : 3475 psig at 220 F
- c : 10.69×10^{-6} psi⁻¹ (6850-6500 psig)

Main differential vaporization data at reservoir temperature :

	Pi	Pb
oil volume factor (bbl/Std bbl) :	1.551	1.617
solution gas-oil ratio (Std cu ft/bbl) :	1028	1028
reservoir fluid viscosity (centipoises) :	0.47	0.35
reservoir fluid density (g/cm ³) :	0.697	0.668
Residual oil gravity :	0.862	60/60 F
	32.7	API

TABLE 1

SAMPLING CONDITIONS

I. RESERVOIR AND WELL CHARACTERISTICS

Producing zone : 3713-3735MD
Static pressure : 6850 psig
Bottom hole temperature : 220 F
Tubing diameter : 3 1/2"
Casing size : 7"
Casing shoe : N/A

II. SAMPLING CONDITIONS

A) SURFACE SAMPLE(S)

Date : N/A
Choke : N/A
Flowing bottom hole pressure : 6659 psig
Well head pressure : 3870 psig
Separator pressure : N/A
well head temperature : N/A
Separator temperature : N/A
Gas rate (Separator) : N/A
Stock tank temperature : N/A
Compressibility factor : N/A
Gas gravity : N/A
Liquid rate (Separator) : N/A
G.L.R. : N/A
Sample(s) received : gas
liq.

B) BOTTOM HOLE SAMPLE(S)

Date : 02/18th/82
Choke : 8/64"
Sample(s) received : 22024/133

COMPANY : AMOCO NORWAY OIL COMPANY

WELL : 2/11-6 (ST1)DST2

SAMPLE(S) VALIDITY

BOTTOM HOLE SAMPLE(S)

1) Sample bottle No 22024/133

Bubble point pressure determination at 72 F is 2708 psig

TABLE 2

BUBBLE POINT PRESSURE DETERMINATION AT 72 F

Bottom hole sample (Cylinder 22024/133)

Pressure (psig)	Pump reading (cm3)
7000	165.24
5000	163.56
4000	162.67
3200	161.89
2725	161.34
Pb= 2708	161.29
2605	160.61
2470	159.63
2265	157.66
1878	152.50

This sample has been used to complete PVT study

BUBBLE POINT PRESSURE DETERMINATION AT 72 F

Bottom hole sample (cylinder 22024/133)

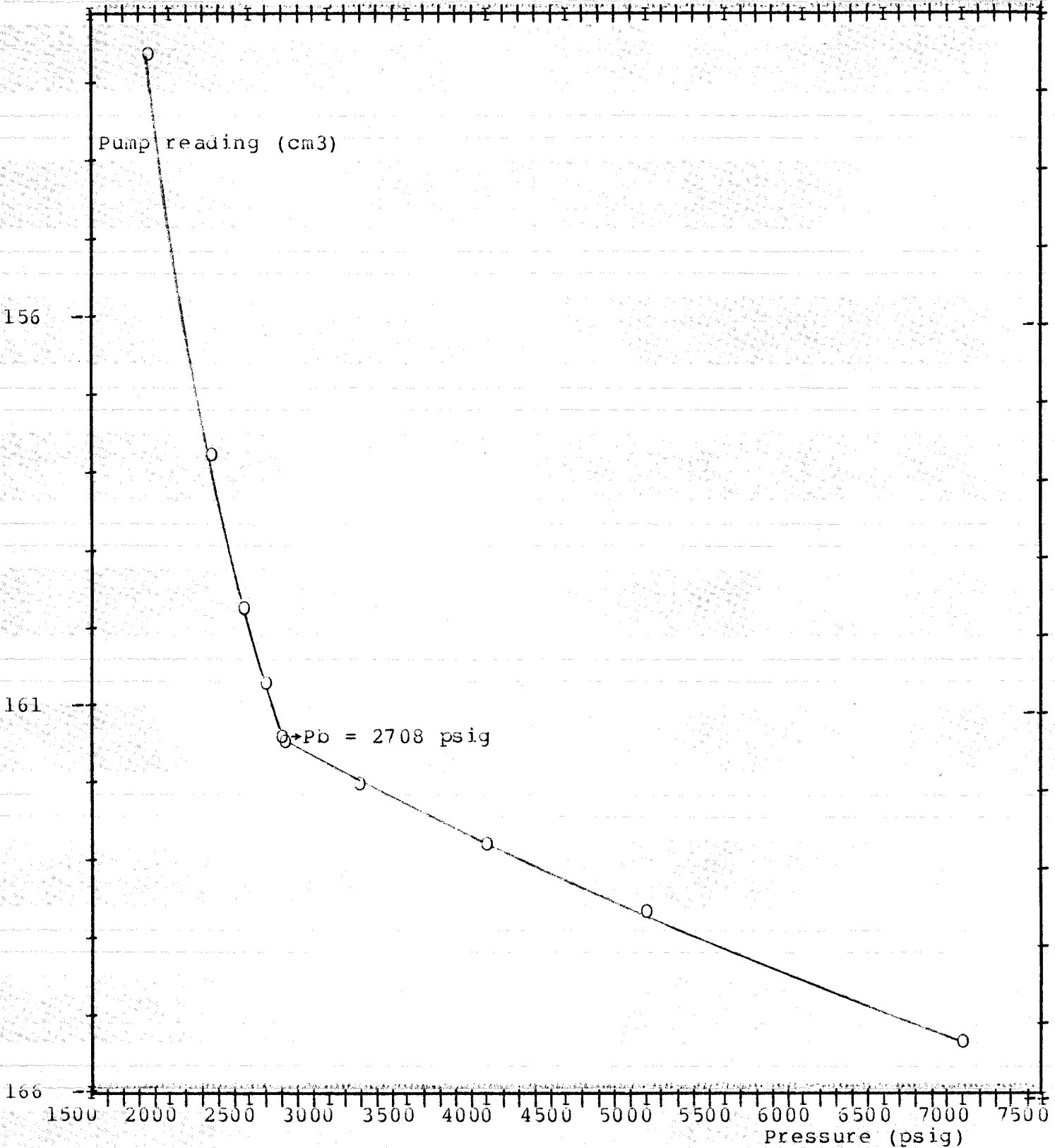


TABLE 3

FLASH OF SEPARATOR LIQUID TO STOCK TANK CONDITIONS

(Molecular composition)

Components	Stock tank liquid (0 psig/ 60 F) (mole percent)	Evolved gas (0 psig/ 60 F) (mole percent)	Recombined separator liquid (10 psig/160 F) (mole percent)
Nitrogen	0.00	0.00	0.00
Carbon dioxide	0.01	1.94	0.04
Hydrogen sulphide	0.00	0.00	0.00
<u>Hydrocarbons:</u>			
Methane	0.01	18.76	0.29
Ethane	0.25	17.64	0.51
Propane	1.93	31.78	2.37
I - Butane	0.65	4.73	0.71
N - Butane	3.40	15.50	3.58
I - Pentane	2.36	3.41	2.38
N - Pentane	3.97	3.09	3.96
Hexanes	7.26	1.53	7.17
Heptanes	11.46	1.15	11.30
Octanes	12.06	0.44	11.88
Nonanes	8.43	0.03	8.31
Decanes	6.61	0.00	6.51
Undecanes	5.11	0.00	5.03
Dodecanes	3.61	0.00	3.55
Tridecanes	3.21	0.00	3.16
Tetradecanes	2.69	0.00	2.65
Pentadecanes	2.39	0.00	2.35
Hexadecanes	1.77	0.00	1.74
Heptadecanes	1.71	0.00	1.69
Octadecanes	1.48	0.00	1.46
Nonadecanes	1.36	0.00	1.34
Eicosanes plus	18.27	0.00	18.02
TOTAL	100.00	100.00	100.00
Molecular weight	201.8	42.642	199.4
Gravity	0.847 60/60 F	1.471 (Air=1)	-----
Molar ratio	98.50	1.50	100.00
Mass ratio	99.68	0.32	100.00

Molecular weight of Eicosanes plus in STO: 526
Gravity of Eicosanes plus in STO : 0.940 (60/60 F)

TABLE 4

MOLECULAR COMPOSITION OF SEPARATOR LIQUID

Components	Recombined Separator liquid (10 psig/160 F) (mole percent)	Separator gas (10 psig/160 F) (mole percent)	Recombined Separator liquid (100 psig/142 F) (mole percent)
Nitrogen	0.00	0.00	0.00
Carbon dioxide	0.04	1.77	0.14
Hydrogen sulphide	0.00	0.00	0.00
<u>Hydrocarbons:</u>			
Methane	0.29	43.69	3.00
Ethane	0.51	16.38	1.50
Propane	2.37	21.63	3.58
I - Butane	0.71	2.84	0.85
N - Butane	3.58	9.02	3.92
I - Pentane	2.38	1.83	2.34
N - Pentane	3.96	1.71	3.82
Hexanes	7.17	0.62	6.76
Heptanes	11.30	0.37	10.62
Octanes	11.88	0.13	11.15
Nonanes	8.31	0.01	7.79
Decanes	6.51	0.00	6.10
Undecanes	5.03	0.00	4.72
Dodecanes	3.55	0.00	3.33
Tridecanes	3.16	0.00	2.96
Tetradecanes	2.65	0.00	2.48
Pentadecanes	2.35	0.00	2.21
Hexadecanes	1.74	0.00	1.64
Heptadecanes	1.69	0.00	1.58
Octadecanes	1.46	0.00	1.37
Nonadecanes	1.34	0.00	1.26
Eicosanes plus	18.02	0.00	16.88
TOTAL	100.00	100.00	100.00
Molecular weight	199.4	32.766	189.0
Gravity	-----	1.131 (Air=1)	-----
Molar ratio	93.74	6.26	100.00
Mass ratio	98.91	1.09	100.00

TABLE 5

MOLECULAR COMPOSITION OF RESERVOIR FLUID

Components	Recombined Separator liquid (100 psig/142 F) (mole percent)	Separator gas (100 psig/142 F) (mole percent)	Recombined Reservoir fluid (mole percent)
Nitrogen	0.00	0.45	0.26
Carbon dioxide	0.14	1.55	0.96
Hydrogen sulphide	0.00	0.00	0.00
<u>Hydrocarbons:</u>			
Metnane	3.00	75.87	45.13
Ethane	1.50	9.39	6.06
Propane	3.58	7.44	5.81
I - Butane	0.85	0.80	0.82
N - Butane	3.92	2.60	3.16
I - Pentane	2.34	0.56	1.31
N - Pentane	3.82	0.65	1.99
Hexanes	6.76	0.38	3.07
Heptanes	10.62	0.23	4.61
Octanes	11.15	0.07	4.74
Nonanes	7.79	0.01	3.29
Decanes	6.10	0.00	2.57
Undecanes	4.72	0.00	1.99
Dodecanes	3.33	0.00	1.41
Tridecanes	2.96	0.00	1.25
Tetradecanes	2.48	0.00	1.05
Pentadecanes	2.21	0.00	0.93
Hexadecanes	1.64	0.00	0.69
Heptadecanes	1.58	0.00	0.67
Octadecanes	1.37	0.00	0.58
Nonadecanes	1.26	0.00	0.53
Eicosanes plus	16.88	0.00	7.12
TOTAL	100.00	100.00	100.00
Molecular weight	189.0	22.584	92.8
Gravity	-----	0.779 (Air=1)	-----
Molar ratio	42.19	57.81	100.00
Mass ratio	85.93	14.07	100.00

Molecular weight of Eicosanes plus in reservoir fluid : 526

TABLE 6

BUBBLE POINT PRESSURE DETERMINATION AND CONSTANT MASS STUDY AT 220 F

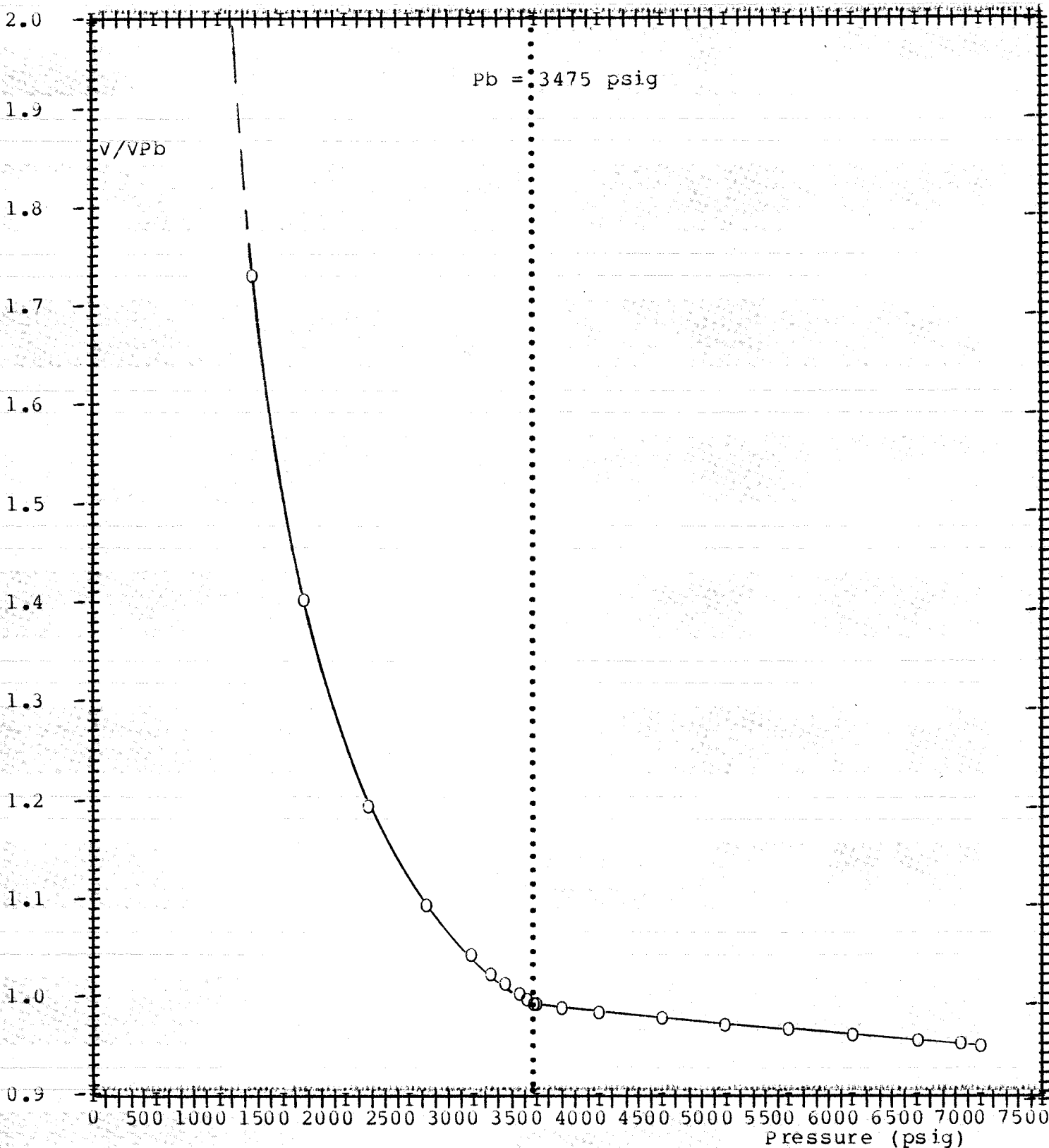
Pressure (psig)	Relative volume V/VPb	Compressibility factor (psi ⁻¹)	Y curve Pb/P-1 V/VPb-1
7000	0.9572		
Pi= 6850	0.9587	10.57 x 10 ⁻⁶	
6500	0.9623	10.69 x 10 ⁻⁶	
6000	0.9676	10.91 x 10 ⁻⁶	
5500	0.9730	11.22 x 10 ⁻⁶	
5000	0.9787	11.65 x 10 ⁻⁶	
4500	0.9846	12.26 x 10 ⁻⁶	
4000	0.9912	13.29 x 10 ⁻⁶	
3700	0.9956	14.96 x 10 ⁻⁶	
3500	0.9993	18.36 x 10 ⁻⁶	
Pb= 3475	1.0000	28.17 x 10 ⁻⁶	
3424	1.0040		3.73
3362	1.0091		3.69
3250	1.0191		3.62
3147	1.0293		3.56
2971	1.0492		3.45
2627	1.1000		3.23
2180	1.2017		2.95
1673	1.4103		2.62
1264	1.7392		2.37
890	2.3638		2.13

Thermal expansion factor of reservoir fluid at 7000 psig

between 70 F and 220 F : = 0.520 x 10⁻³ F⁻¹

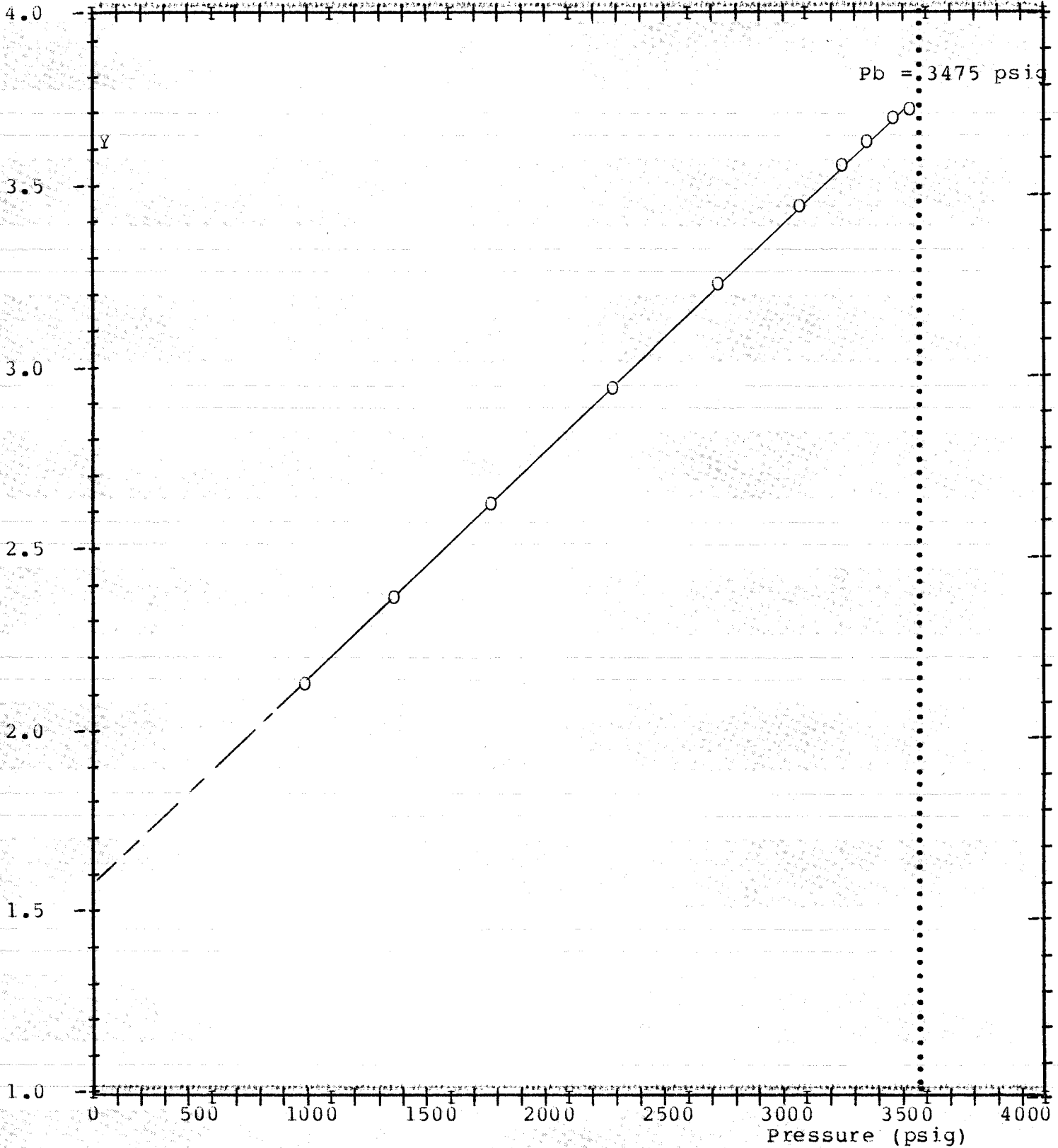
BUBBLE POINT PRESSURE DETERMINATION AND CONSTANT MASS STUDY AT 220 F

Relative volume



BUBBLE POINT PRESSURE DETERMINATION AND CONSTANT MASS STUDY AT 220 F

Y curve pressure-volume function



DIFFERENTIAL VAPORIZATION OF RESERVOIR FLUID AT 220 F

Compressibility factor Z

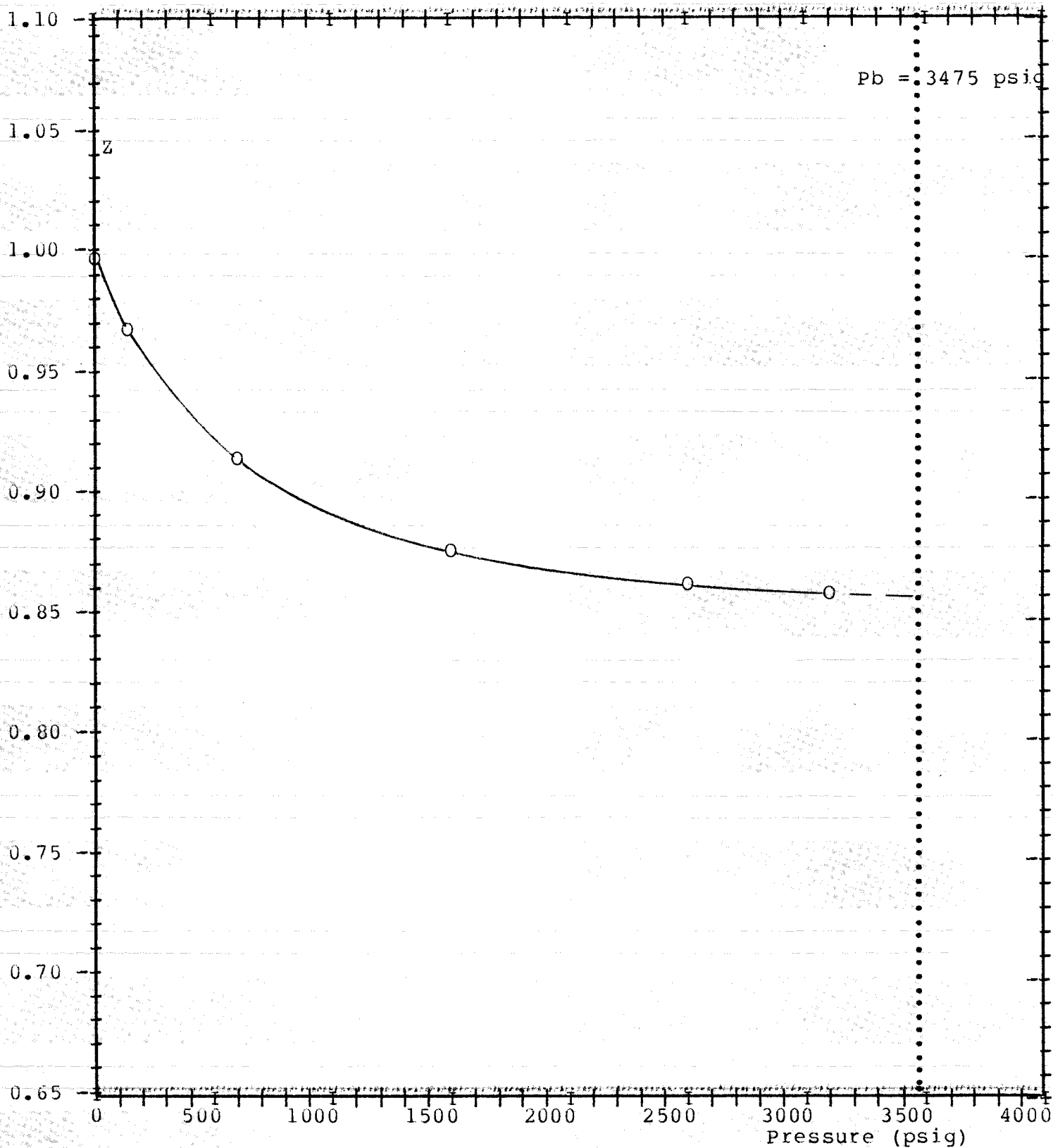


TABLE 7

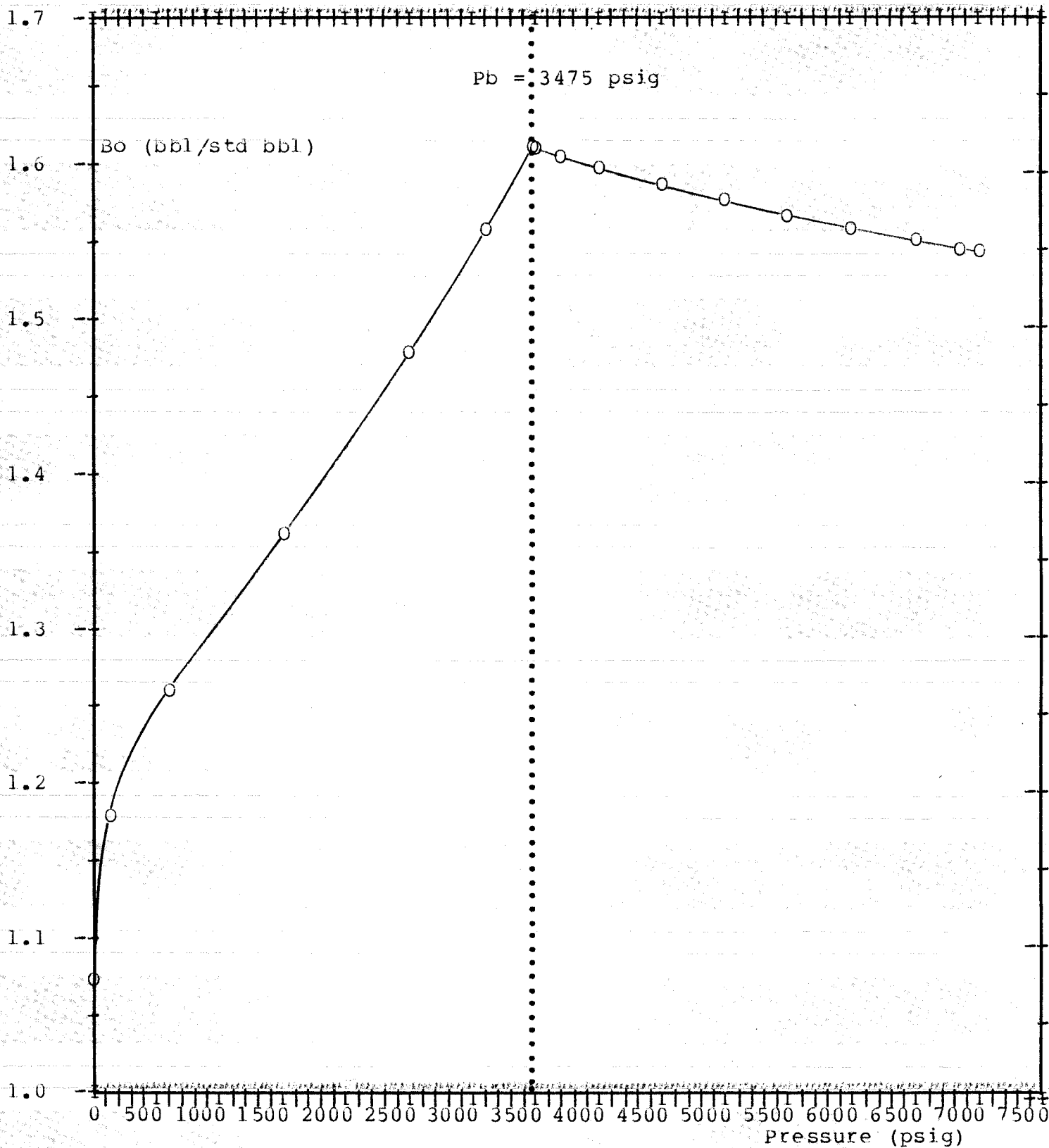
DIFFERENTIAL VAPORIZATION OF RESERVOIR FLUID AT 220 F

Pressure (psig)	Oil volume factor Bo (bbl/Std bbl)	Solution gas-oil ratio Rs (Std cu ft/Std bbl)	Gas volume factor Bg (cu ft/Std cu ft)	Reservoir oil density (g/cm ³)
Pi= 7000	1.549			0.698
6850	1.551			0.697
6500	1.557			0.695
6000	1.564			0.691
5500	1.573			0.687
5000	1.583			0.683
4500	1.593			0.679
4000	1.604			0.674
3700	1.611			0.671
3500	1.616			0.669
Pb= 3475	1.617	1028		0.668
3100	1.560	902	0.53 x 10 ⁻²	0.680
2500	1.480	731	0.66 x 10 ⁻²	0.698
1500	1.362	478	1.12 x 10 ⁻²	0.728
600	1.260	262	2.87 x 10 ⁻²	0.756
139	1.179	126	12.15 x 10 ⁻²	0.780
0	1.074	0	-----	0.803

Residual oil gravity : 0.862 60/60 F
32.7 API

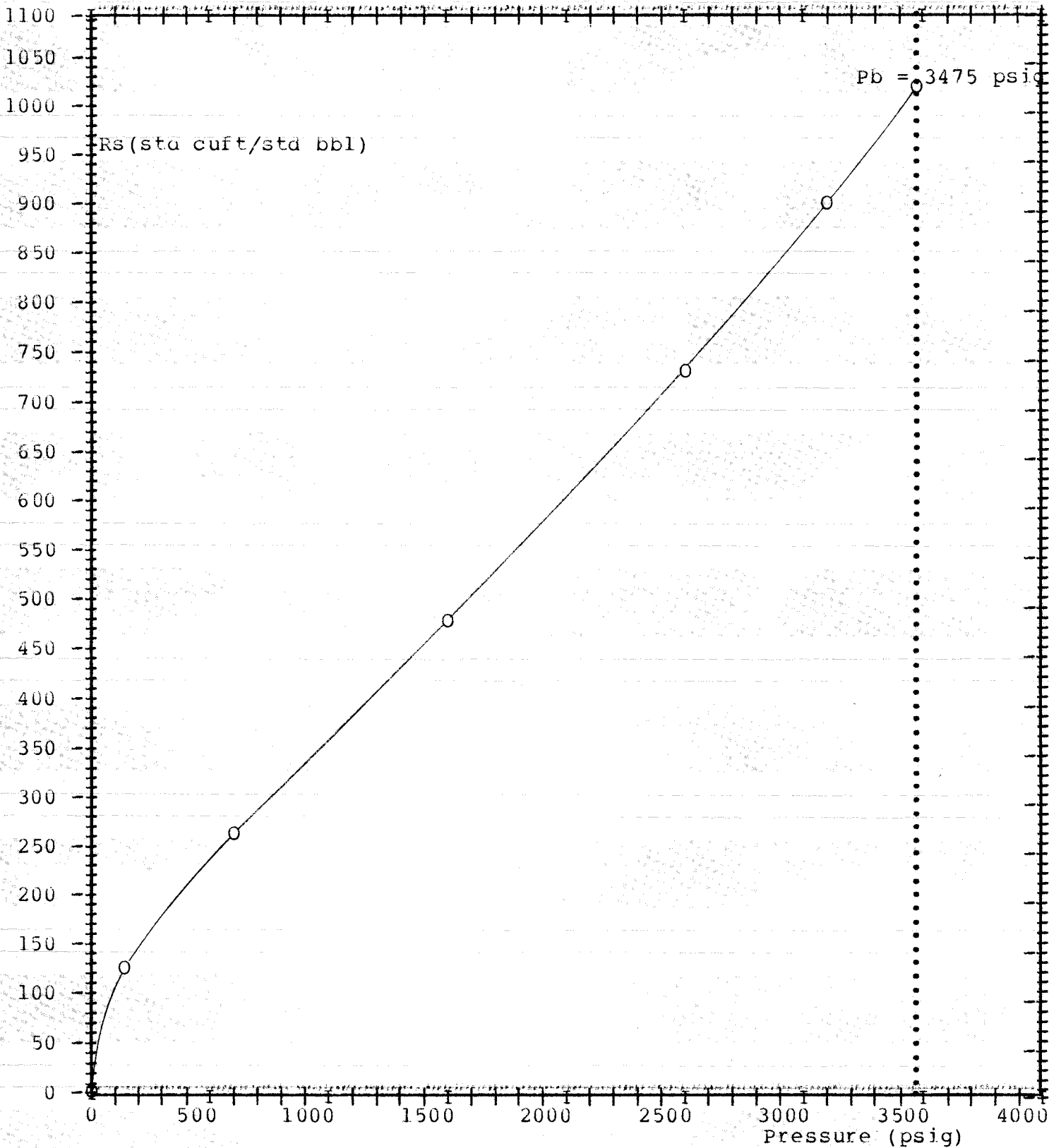
DIFFERENTIAL VAPORIZATION OF RESERVOIR FLUID AT 220 F

Oil volume factor



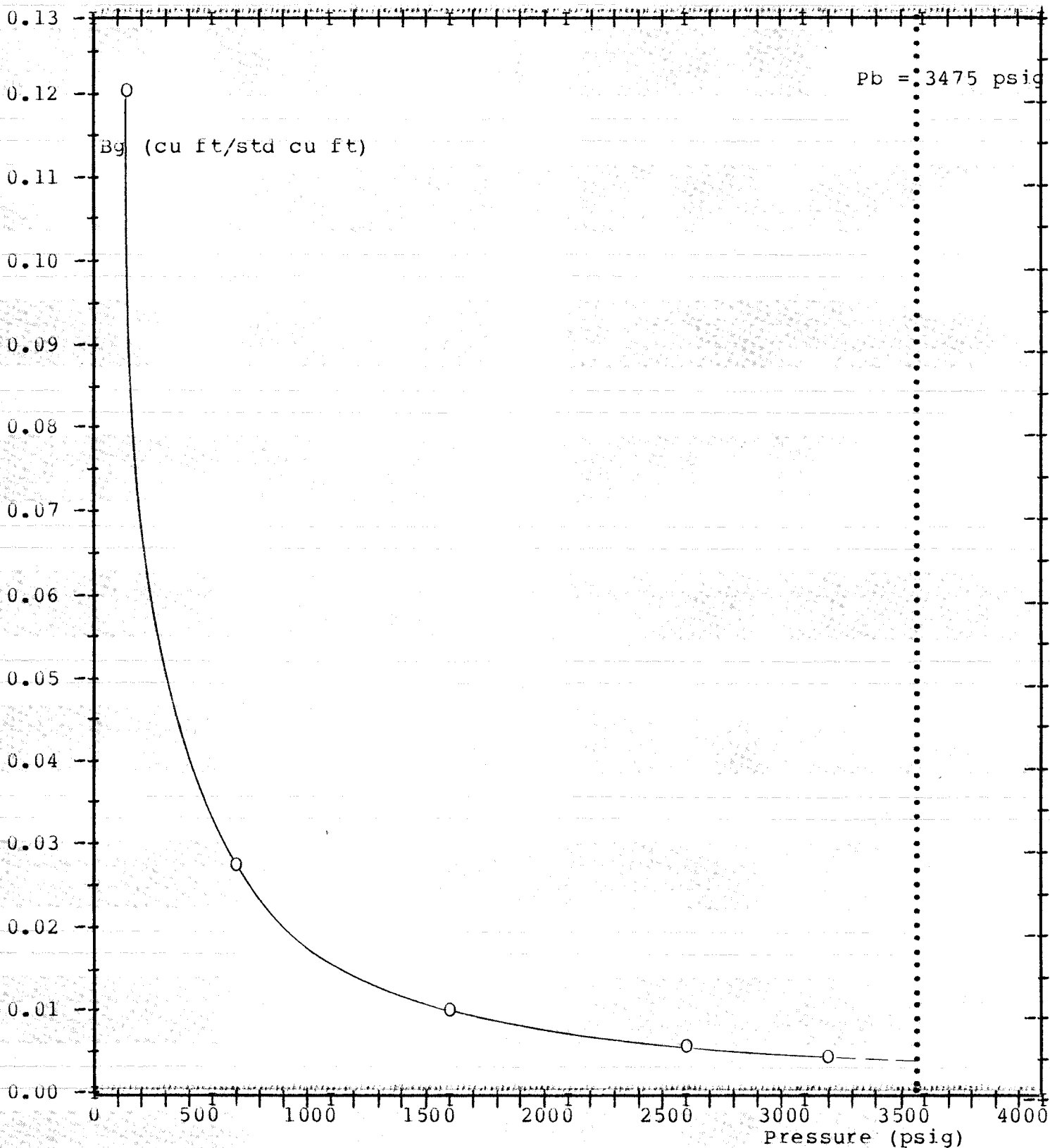
DIFFERENTIAL VAPORIZATION OF RESERVOIR FLUID AT 220 F

Solution gas oil ratio



DIFFERENTIAL VAPORIZATION OF RESERVOIR FLUID AT 220. F.

Gas volume factor



DIFFERENTIAL VAPORIZATION OF RESERVOIR FLUID AT 220 F

Reservoir oil density

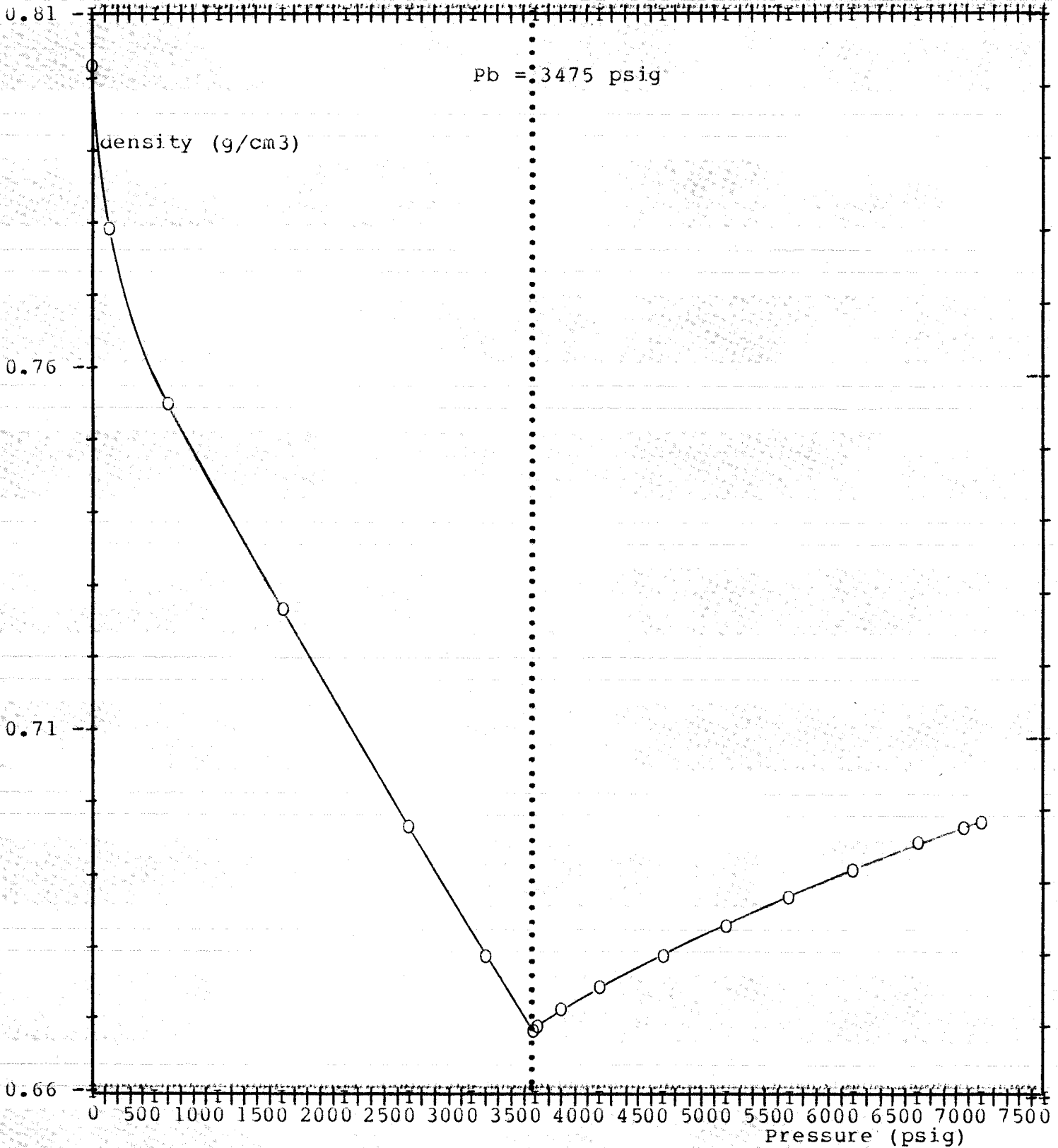


TABLE 8

DIFFERENTIAL VAPORIZATION OF RESERVOIR FLUID AT 220 F

Molecular composition of liberated gases (mole percent)

Pressure (psig)	3100	2500	1500	600	139	0
Nitrogen	0.61	0.38	0.13	0.00	0.00	0.00
Carbon dioxide	1.22	1.25	1.38	1.69	1.70	0.60
Hydrogen sulphide	0.00	0.00	0.00	0.00	0.00	0.00

Hydrocarbons:

Methane	80.80	81.63	80.66	73.43	48.97	9.27
Ethane	6.56	6.64	7.44	10.33	15.64	10.09
Propane	5.00	4.92	5.38	8.00	17.14	27.74
I - Butane	0.60	0.57	0.59	0.86	2.11	4.25
N - Butane	2.09	1.97	2.07	2.90	7.37	18.07
I - Pentane	0.61	0.56	0.55	0.70	1.88	6.33
N - Pentane	0.78	0.72	0.71	0.87	2.31	8.47
Hexanes	0.75	0.64	0.55	0.62	1.57	7.87
Heptanes plus	0.98	0.72	0.54	0.60	1.31	12.31

TOTAL	100.00	100.00	100.00	100.00	100.00	105.00
Molecular weight	22.094	21.627	21.688	23.638	32.122	61.128
Gravity (Air=1)	0.762	0.746	0.748	0.816	1.108	2.109
Molecular weight of neptanes plus	105.4	105.1	104.6	104.6	104.6	111.1

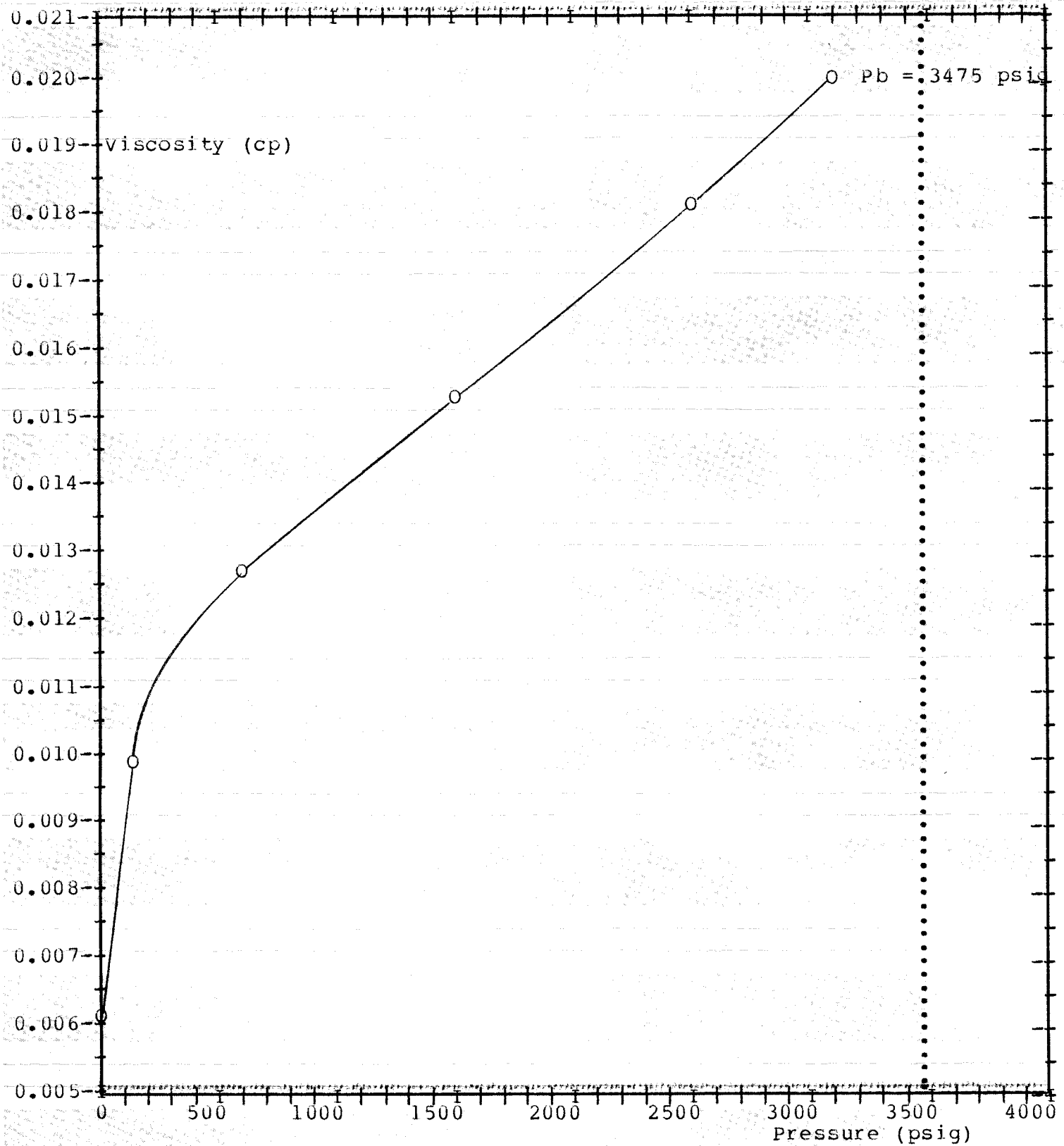
TABLE 9

DIFFERENTIAL VAPORIZATION OF RESERVOIR FLUID AT 220 F

Pressure (psig)	Gas viscosity (centipoises)	Gas gravity (Air=1)	compressibility factor Z
3100	0.0201	0.762	0.861
2500	0.0181	0.746	0.865
1500	0.0153	0.748	0.879
600	0.0127	0.816	0.917
139	0.0099	1.108	0.971
0	0.0061	2.109	1.000

DIFFERENTIAL VAPORIZATION OF RESERVOIR FLUID AT 220. F.

liberated gas viscosity



DIFFERENTIAL VAPORIZATION OF RESERVOIR FLUID AT 220 F

Liberated gas gravity

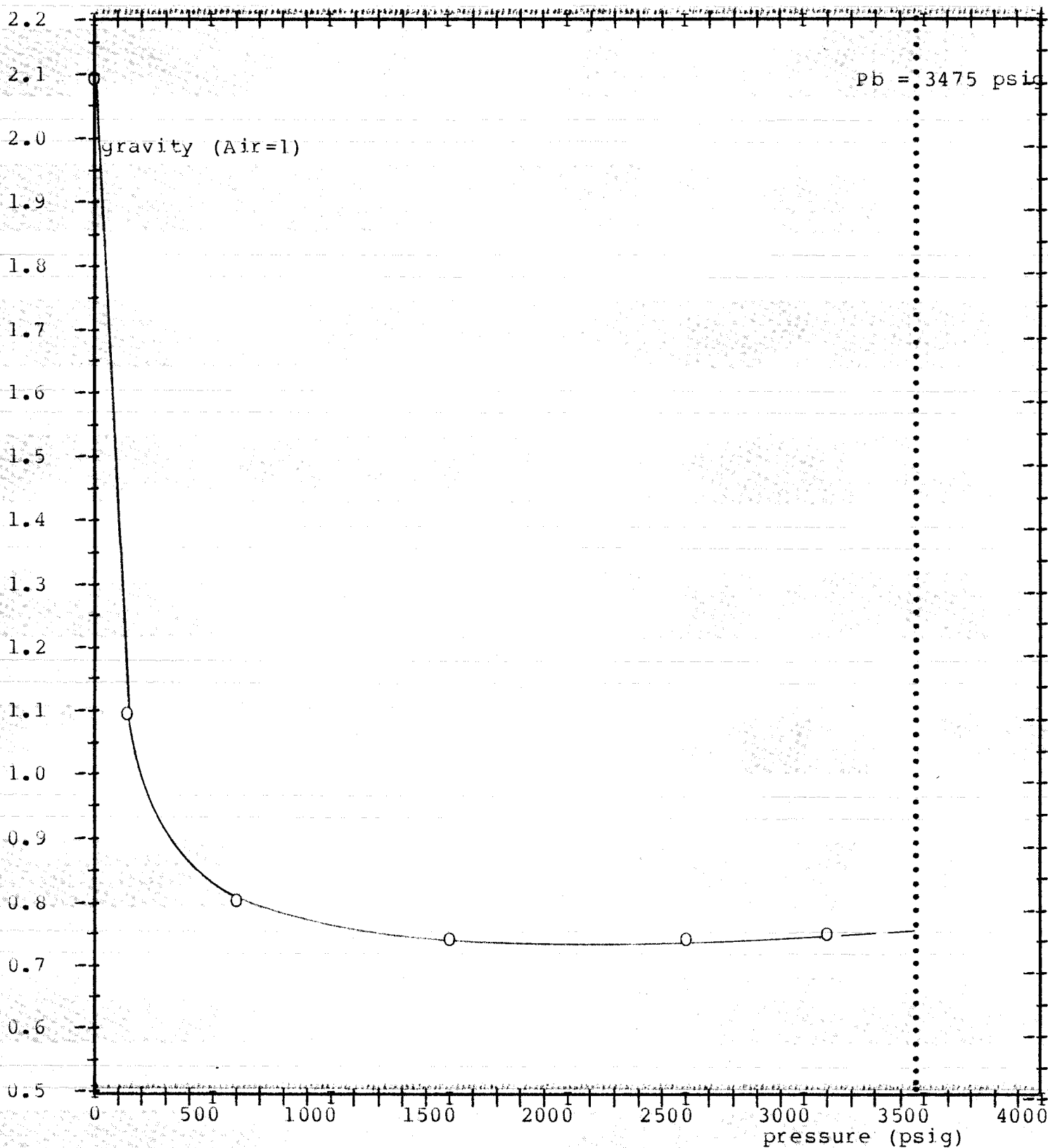


TABLE 10

SEPARATION TEST OF RESERVOIR FLUID

Separator		Gas-oil ratio (1) (Std cu ft/std bbl)			Oil volume factor (2) (bbl/Std bbl)	Sep. liq. density (g/cm ³)	Shrinkage factor (3) (Std bbl/bbl)	sto gravity (60/60 F)
Pres. (psig)	Temp. (F)	Sep.	Tank	Total				
100	142	829	-	-	-	0.789	0.919	-
10	160	38	-	-	-	0.802	0.943	-
0	60	-	9	876	1.496	-	1.000	0.847

(1) Gas volume at standard conditions per volume of stock tank oil at 60 F

(2) Volume of reservoir fluid at saturation pressure per volume of stock tank oil at 60 F

(3) volume of stock tank oil at 60 F per volume of separator liquid at separator conditions

TABLE 11

SEPARATION TEST OF RESERVOIR FLUID

Molecular composition of liberated gases (mole percent)

Pressure (psig)	100	10	0
Temperature (F)	142	160	60
Nitrogen	0.45	0.00	0.00
Carbon dioxide	1.55	1.77	1.94
Hydrogen sulphide	0.00	0.00	0.00

Hydrocarbons:

Methane	75.87	43.69	18.76
Ethane	9.39	16.38	17.64
Propane	7.44	21.63	31.78
I - Butane	0.80	2.84	4.73
N - Butane	2.60	9.02	15.50
I - Pentane	0.56	1.83	3.41
N - Pentane	0.65	1.71	3.09
Hexanes	0.38	0.62	1.53
Heptanes plus	0.31	0.51	1.62

TOTAL	100.00	100.00	100.00
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Molecular weight	22.584	32.766	42.642
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Gravity (Air=1)	0.779	1.131	1.471
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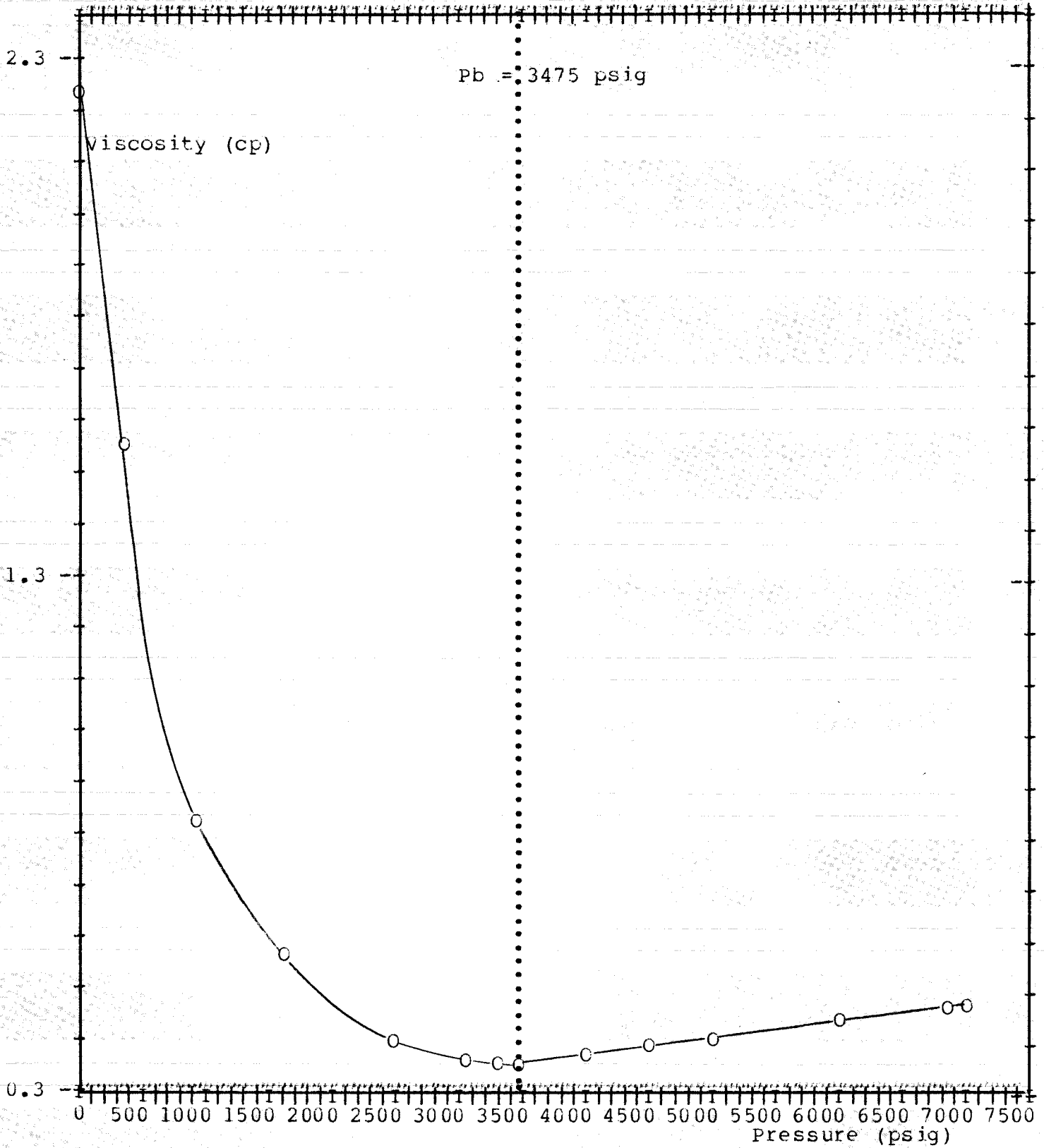
Molecular weight of heptanes plus	104.3	104.3	104.5
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TABLE 12

VISCOSITY OF RESERVOIR FLUID AT 220 F

Pressure (psig)	Viscosity (centipoises)
7000	0.48
Pi= 6850	0.47
6000	0.44
5000	0.40
4500	0.39
4000	0.37
Pb= 3475	0.35
3300	0.36
3050	0.37
2480	0.41
1620	0.58
920	0.84
360	1.57
0	2.25

VISCOSITY OF RESERVOIR FLUID AT 220 F



ADDITIONAL ANALYSIS

A) Pour point on residual liquid
from differential vaporization : 17 F

B) Reid vapor pressure on STO : 6.6 psi
Norm ASTM D-323

NOMENCLATURE

- P : Pressure
V : Volume
T : Temperature
P_i : Initial static pressure
P_b : Bubble point pressure
P_d : Dew point pressure
V_r=V/V_{Pb} : Relative volume (oil reservoir fluid)
V_r=V/V_{Pd} : Relative volume (gas reservoir fluid)
 $c = - \frac{1}{V} \frac{dV}{dP}$: Compressibility factor of reservoir fluid

 $\alpha = \frac{1}{V} \frac{dV}{dT}$: Thermal expansion of reservoir fluid

 $Y = \frac{P_b/P - 1}{V_r - 1}$: Dimensionless compressibility function

B_o : Oil formation volume factor
R_s : Solution gas oil ratio
Z : Gas compressibility factor or gas deviation factor
B_g : Gas formation volume factor
 ρ_o : Reservoir oil density
G_o : Residual oil gravity
G : Gas gravity (Air=1)
sto : Stock tank oil
GOR : Gas oil ratio
GLR : Gas liquid ratio
WOR : Water liquid ratio
Shrinkage factor : $\frac{\text{Oil volume at standard conditions}}{\text{Oil volume at separator conditions}}$

 $Z = \frac{PV}{nRT}$: n=Total moles of a mixture in the gas state
R=Universal gas constant (per mole)

GPM : Gallons per thousand standard cubic feet
Standard conditions : For gas volumes =60 F and 14.7 psia
: For oil measurements=60 F and atmospheric pressure

Gross heat content is calculated from API research project 44
Molecular weights, densities, critical values are from CRC Handbook of chemistry and physics
Gas viscosity is calculated with equations from Standing (Behavior of oil field hydrocarbon systems)