

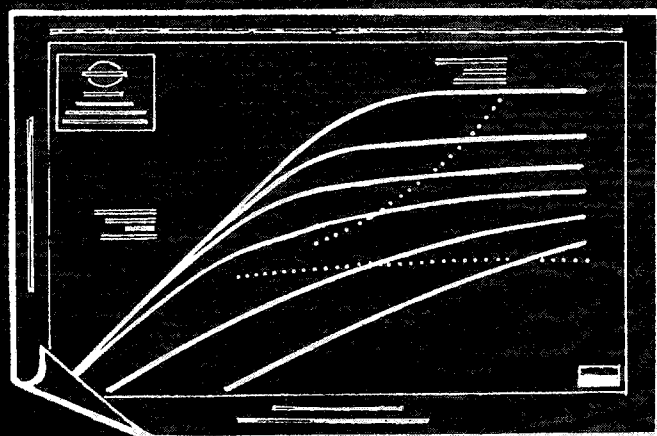
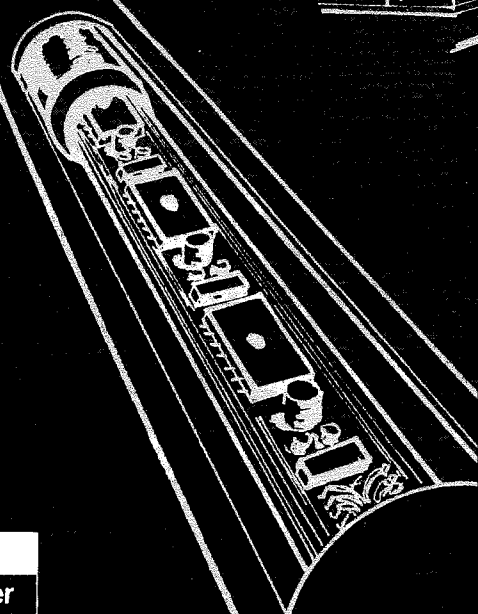
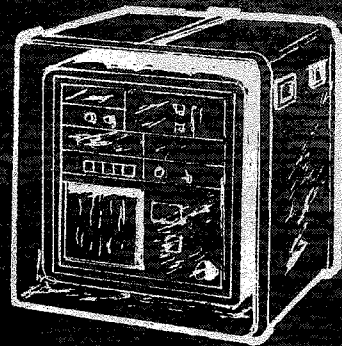
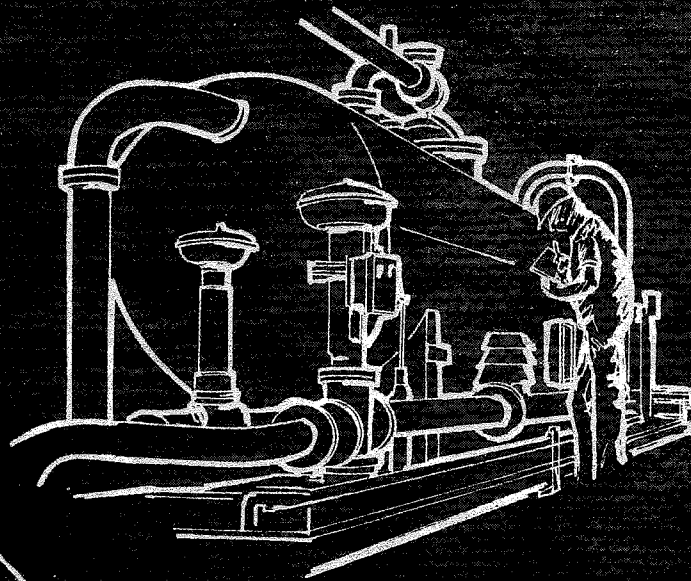
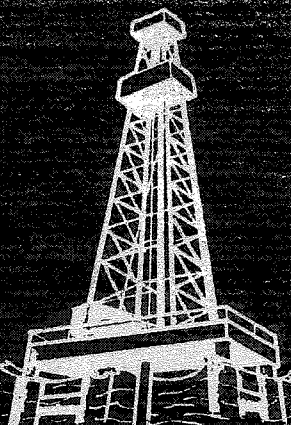
BP027327

FLOPETROL

P.V.T. STUDY REPORT

Client: AMOCO NORWAY OIL COMPANY
Field : TOR FORM. Well : 2/11-6 (ST1) DST2
Zone : 3685-3706m Samp. date: 02/16th/82

Report #: 82/L/040 Date: APRIL 1982



FLOPETROL
Schlumberger

P.V.T.STUDY REPORT

Client:AMOCO NORWAY OIL COMPANY
Field :TOR FORM. Well :2/11-6 (ST1)DST2
Zone :3685-3706m Samp. date:02/16th/82

Report #:82/L/040 Date: APRIL 1982

HEADQUARTERS LABORATORY

INDEX

- ANNEX 1: SAMPLING CONDITIONS AND SAMPLE(S) VALIDITY
- ANNEX 2: MOLECULAR COMPOSITION OF FIELD SEPARATOR GAS(ES)
- ANNEX 3: RECOMBINATION OF SEPARATOR SAMPLES
- ANNEX 4: MOLECULAR COMPOSITION OF RESERVOIR FLUID(S)
- ANNEX 5: CONSTANT MASS STUDY
- ANNEX 6: DIFFERENTIAL VAPORIZATION
- ANNEX 7: SEPARATION TEST(S)
- ANNEX 8: VISCOSITY
- ANNEX 9: ADDITIONNAL ANALYSIS
- ANNEX 10:
- ANNEX 11:
- ANNEX 12: NOMENCLATURE AND SYSTEM OF UNITS

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 : 3323 psig at 220 F
- c : $12.06 \times 10^{-6} \text{ psi}^{-1}$ (6850-6000 psig)

Main differential vaporization data at reservoir temperature :

	Pi	Pb
oil volume factor (bbl/Std bbl)	1.535	1.607
solution gas-oil ratio (Std cu ft/bbl)	1021	1021
reservoir fluid viscosity (centipoises)	0.49	0.36
reservoir fluid density (g/cm ³)	0.707	0.675
Residual oil gravity	0.863	60/60 F
	32.5	API

TABLE 1

SAMPLING CONDITIONS

I. RESERVOIR AND WELL CHARACTERISTICS

Producing zone	:	3685-3706m
Static pressure	:	6850 psig
Bottom hole temperature	:	220 F
Tubing diameter	:	3 1/2" D.P.
Casing size	:	7"
Casing shoe	:	N/A

II. SAMPLING CONDITIONS

A) SURFACE SAMPLE(S)

Date	:	N/A
Choke	:	N/A
Flowing bottom hole pressure	:	N/A
Well head pressure	:	2906 psig
Separator pressure	:	245 psig
Well head temperature	:	70 F
Separator temperature	:	52 F
Gas rate (Separator)	:	395 M std cu ft/day
Stock tank temperature	:	N/A
Compressibility factor	:	N/A
Gas gravity	:	0.690 (Air=1)
Liquid rate (Separator)	:	707 bbl/day
G.L.R.	:	559 std cu ft/bbl
Sample(s) received	:	gas
		liq.

B) BOTTOM HOLE SAMPLE(S)

Date	:	02/16th/82
Choke	:	8/64"
Sample(s) received	:	9209/93

SAMPLE(S) VALIDITY

BOTTOM HOLE SAMPLE(S)

1) Sample bottle No 9209/93

Bubble point pressure determination at 70 F is 2585 psig

TABLE 2

BUBBLE POINT PRESSURE DETERMINATION AT 70 F

Bottom hole sample (Cylinder 9209/93)

Pressure (psig)	Pump reading (cm3)
7000	186.94
6000	186.14
5000	185.24
4000	184.32
3500	183.82
3000	183.24
Pb= 2585	182.77
2525	182.38
2460	181.91
2355	181.02
2140	178.71
1840	173.76

This sample has been used to complete PVT study

BUBBLE POINT PRESSURE DETERMINATION AT 70 F

Bottom hole sample (cylinder 9209/93)

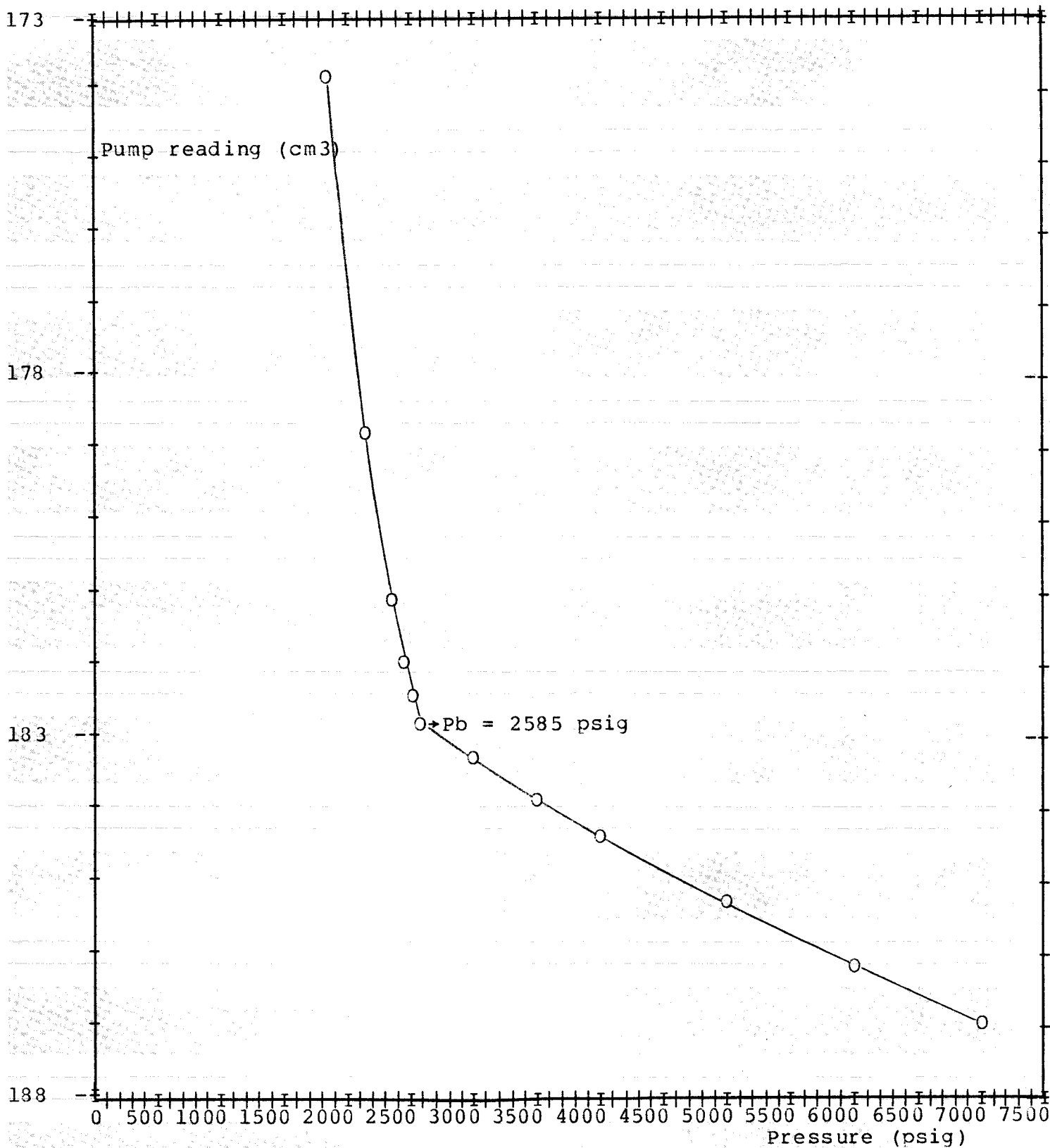


TABLE 3

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	0.03	1.08	0.04
Hydrogen sulphide	0.00	0.00	0.00
<u>Hydrocarbons:</u>			
Methane	0.02	18.55	0.26
Ethane	0.29	15.65	0.49
Propane	1.68	31.29	2.06
I - Butane	0.52	5.07	0.58
N - Butane	2.44	17.79	2.64
I - Pentane	2.18	4.21	2.21
N - Pentane	3.62	3.61	3.62
Hexanes	7.38	1.48	7.30
Heptanes	11.85	0.88	11.71
Octanes	12.59	0.35	12.43
Nonanes	8.93	0.04	8.82
Decanes	7.07	0.00	6.98
Undecanes	5.37	0.00	5.30
Dodecanes	4.07	0.00	4.02
Tridecanes	3.93	0.00	3.88
Tetradecanes	3.11	0.00	3.07
Pentadecanes	2.77	0.00	2.73
Hexadecanes	1.95	0.00	1.93
Heptadecanes	1.70	0.00	1.68
Octadecanes	1.47	0.00	1.45
Nonadecanes	1.35	0.00	1.33
Eicosanes plus	15.68	0.00	15.47
TOTAL	100.00	100.00	100.00
Molecular weight	196.4	43.493	194.5
Gravity	0.846 60/60 F	1.501 (Air=1)	-----
Molar ratio	98.72	1.28	100.00
Mass ratio	99.71	0.29	100.00

Molecular weight of Eicosanes plus in STO: 542
Gravity of Eicosanes plus in STO : 0.946 (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	0.78	0.09
Hydrogen sulphide	0.00	0.00	0.00
<u>Hydrocarbons:</u>			
Methane	0.26	43.71	3.08
Ethane	0.49	17.47	1.59
Propane	2.06	22.32	3.38
I - Butane	0.58	2.85	0.72
N - Butane	2.64	8.87	3.04
I - Pentane	2.21	1.72	2.18
N - Pentane	3.62	1.49	3.49
Hexanes	7.30	0.44	6.86
Heptanes	11.71	0.23	10.97
Octanes	12.43	0.10	11.63
Nonanes	8.82	0.02	8.25
Decanes	6.98	0.00	6.52
Undecanes	5.30	0.00	4.96
Dodecanes	4.02	0.00	3.75
Tridecanes	3.88	0.00	3.63
Tetradecanes	3.07	0.00	2.87
Pentadecanes	2.73	0.00	2.55
Hexadecanes	1.93	0.00	1.80
Heptadecanes	1.68	0.00	1.57
Octadecanes	1.45	0.00	1.35
Nonadecanes	1.33	0.00	1.25
Eicosanes plus	15.47	0.00	14.47
TOTAL	100.00	100.00	100.00
Molecular weight	194.5	32.329	184.0
Gravity	-----	1.116 (Air=1)	-----
Molar ratio	93.51	6.49	100.00
Mass ratio	98.86	1.14	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	0.37	0.21
Carbon dioxide	0.09	0.79	0.48
Hydrogen sulphide	0.00	0.00	0.00
<u>Hydrocarbons:</u>			
Methane	3.08	76.55	44.21
Ethane	1.59	9.79	6.18
Propane	3.38	7.44	5.65
I - Butane	0.72	0.78	0.76
N - Butane	3.04	2.53	2.75
I - Pentane	2.18	0.53	1.25
N - Pentane	3.49	0.60	1.87
Hexanes	6.86	0.34	3.21
Heptanes	10.97	0.21	4.95
Octanes	11.63	0.06	5.15
Nonanes	8.25	0.01	3.64
Decanes	6.52	0.00	2.87
Undecanes	4.96	0.00	2.18
Dodecanes	3.75	0.00	1.65
Tridecanes	3.63	0.00	1.60
Tetradecanes	2.87	0.00	1.26
Pentadecanes	2.55	0.00	1.12
Hexadecanes	1.80	0.00	0.79
Heptadecanes	1.57	0.00	0.69
Octadecanes	1.35	0.00	0.60
Nonadecanes	1.25	0.00	0.55
Eicosanes plus	14.47	0.00	6.38
TOTAL	100.00	100.00	100.00
Molecular weight	184.0	22.281	93.5
Gravity	-----	0.769 (Air=1)	-----
Molar ratio	44.03	55.97	100.00
Mass ratio	86.66	13.34	100.00

Molecular weight of Eicosanes plus in reservoir fluid : 542

TABLE 6

BUBBLE POINT PRESSURE DETERMINATION AND CONSTANT MASS STUDY AT 220 F

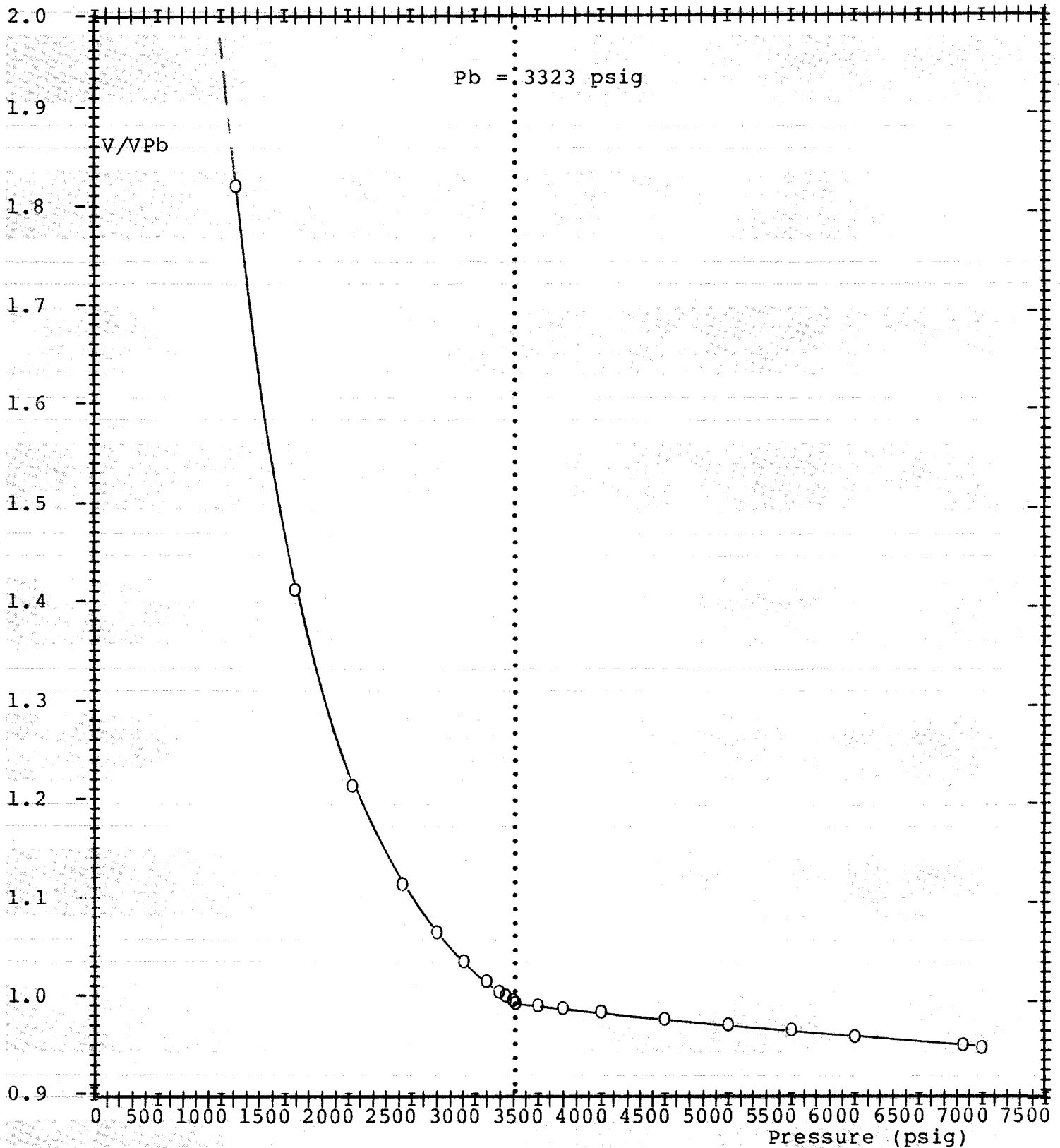
Pressure (psig)	Relative volume V/VPb	Compressibility factor (psi ⁻¹)	Y curve Pb/P-1 V/VPb-1
7000	0.9529		
Pi= 6850	0.9546	11.86 x 10 ⁻⁶	
6000	0.9643	12.06 x 10 ⁻⁶	
5500	0.9703	12.29 x 10 ⁻⁶	
5000	0.9764	12.57 x 10 ⁻⁶	
4500	0.9827	12.95 x 10 ⁻⁶	
4000	0.9894	13.57 x 10 ⁻⁶	
3700	0.9936	14.43 x 10 ⁻⁶	
3500	0.9967	15.54 x 10 ⁻⁶	
Pb= 3323	1.0000	18.53 x 10 ⁻⁶	
3303	1.0017		3.54
3247	1.0067		3.51
3197	1.0113		3.49
3097	1.0213		3.43
2922	1.0411		3.34
2707	1.0705		3.23
2426	1.1200		3.08
2036	1.2198		2.88
1579	1.4192		2.63
1115	1.8283		2.39
828	2.3455		2.24

Thermal expansion factor of reservoir fluid at 7000 psig

between 70 F and 220 F : = 0.529 x 10⁻³ F⁻¹

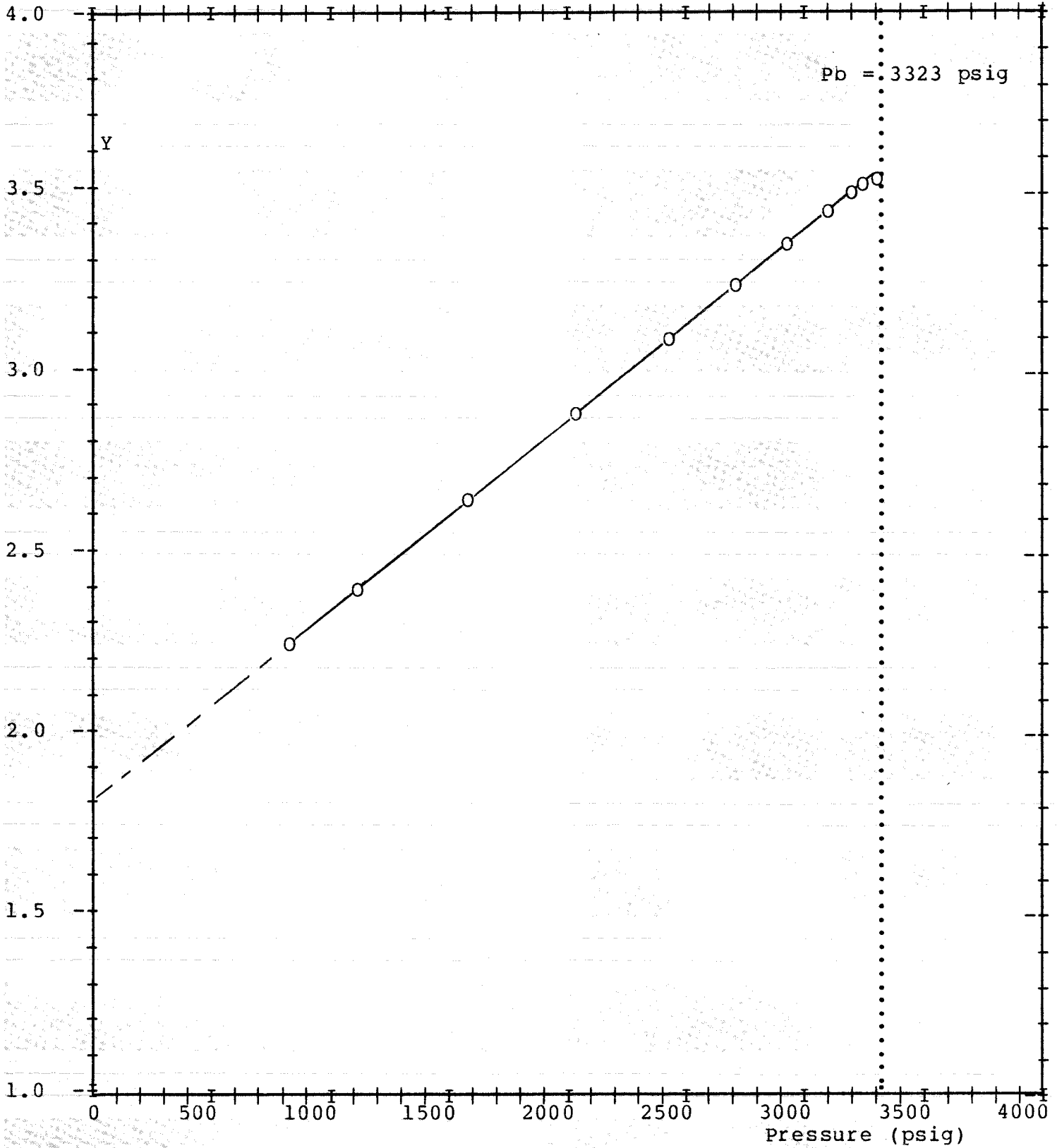
BUBBLE POINT PRESSURE DETERMINATION AND CONSTANT MASS STUDY AT 220 F

Relative volume



BUBBLE POINT PRESSURE DETERMINATION AND CONSTANT MASS STUDY AT 220 F

Y curve pressure-volume function



Pb = 3323 psig

TABLE 7

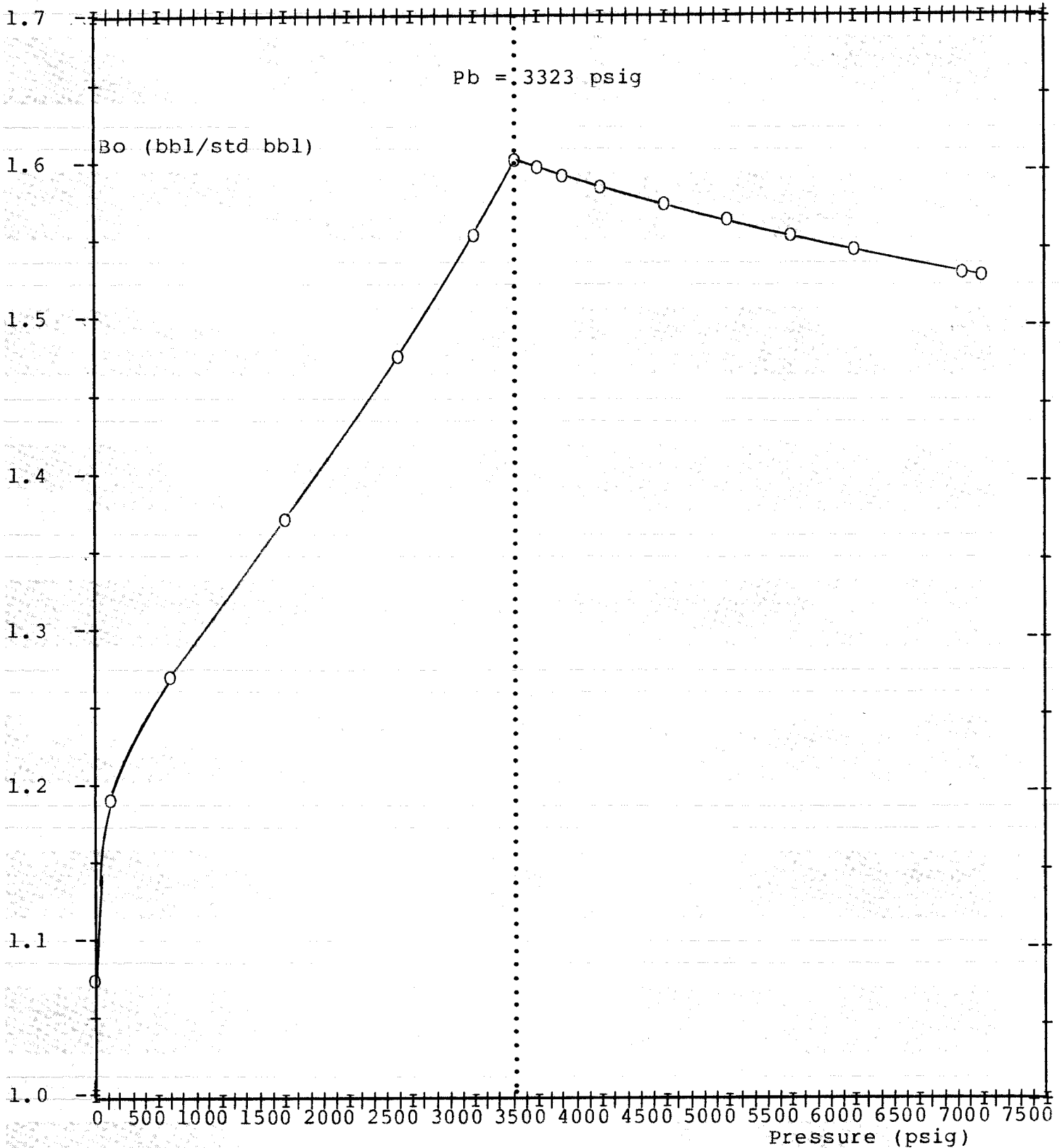
DIFFERENTIAL VAPORIZATION OF RESERVOIR FLUID AT 220 F

Pressure (psig)	Oil volume factor B _o (bbl/Std bbl)	Solution gas-oil ratio R _s (Std cu ft/Std bbl)	Gas volume factor B _g (cu ft/Std cu ft)	Reservoir oil density (g/cm ³)
Pi= 7000	1.533			0.708
6850	1.535			0.707
6000	1.549			0.700
5500	1.558			0.696
5000	1.568			0.691
4500	1.578			0.687
4000	1.590			0.682
3700	1.597			0.679
3500	1.602			0.677
Pb= 3323	1.607	1021		0.675
3000	1.554	917	0.55 x 10 ⁻²	0.687
2400	1.476	747	0.69 x 10 ⁻²	0.704
1500	1.371	518	1.12 x 10 ⁻²	0.731
600	1.269	301	2.92 x 10 ⁻²	0.760
129	1.190	134	13.13 x 10 ⁻²	0.777
0	1.073	0	-----	0.804

Residual oil gravity : 0.863 60/60 F
32.5 API

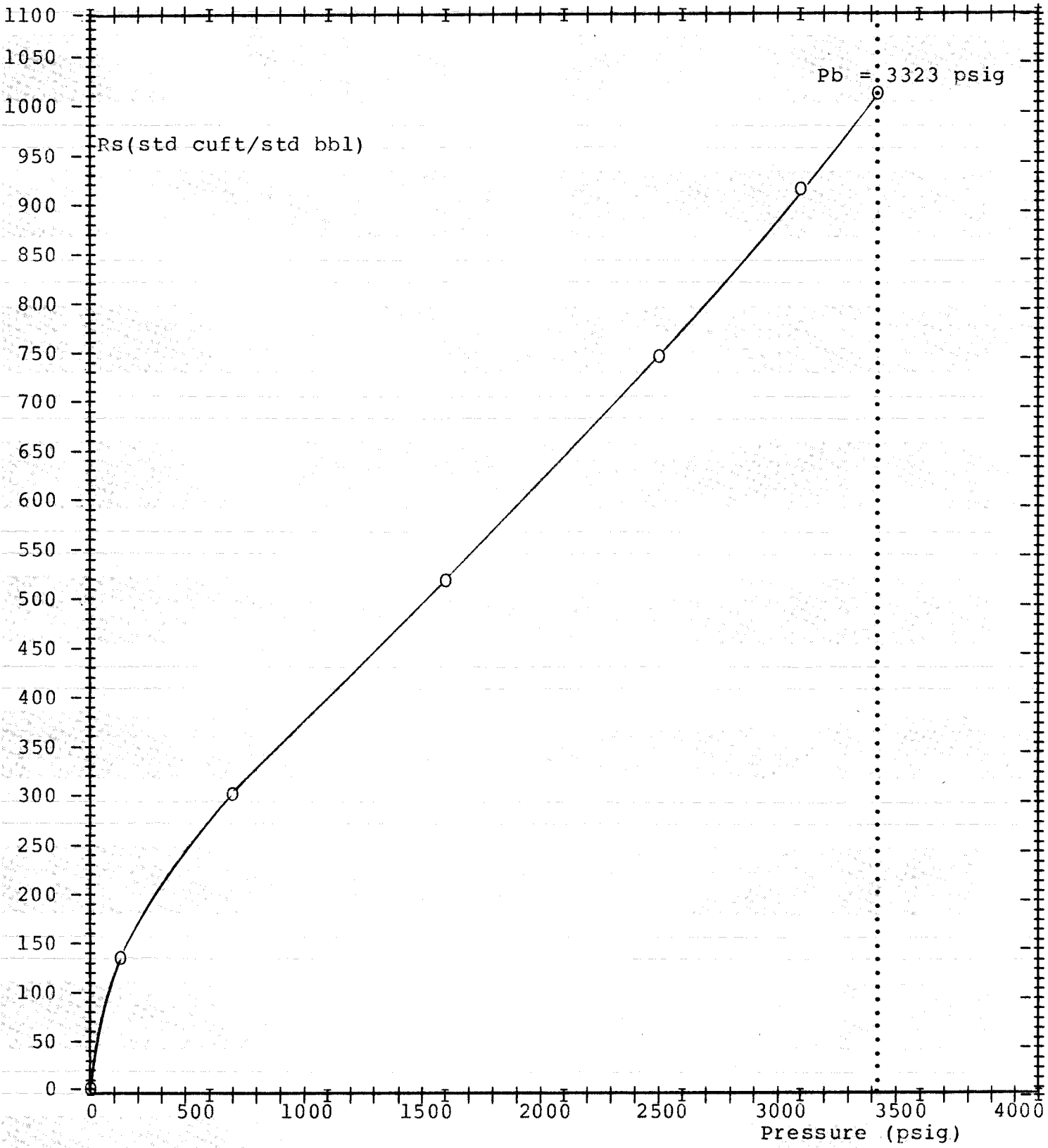
DIFFERENTIAL VAPORIZATION OF RESERVOIR FLUID AT 220 F

Oil volume factor



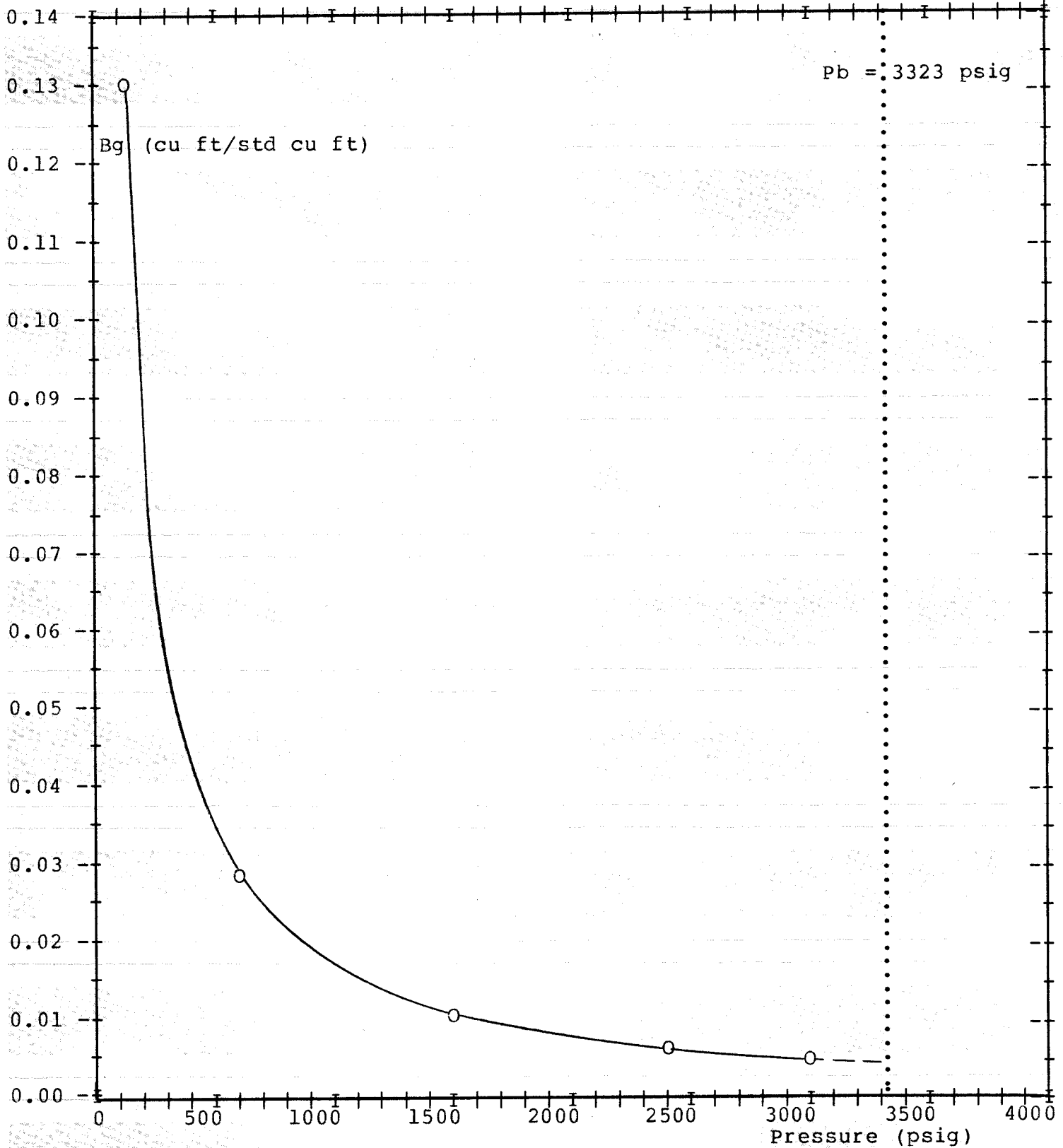
DIFFERENTIAL VAPORIZATION OF RESERVOIR FLUID AT 220 F

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

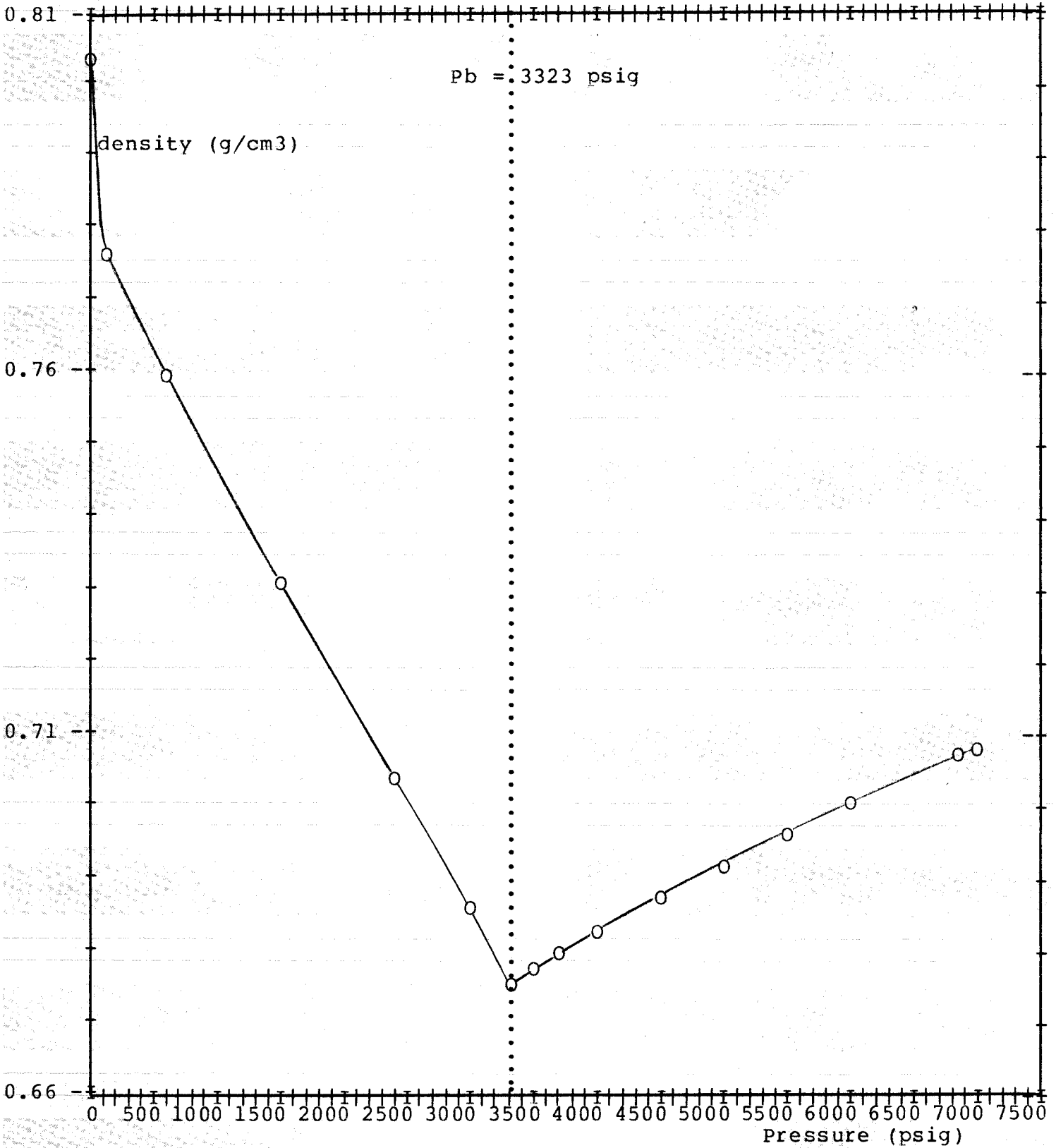


TABLE 8

DIFFERENTIAL VAPORIZATION OF RESERVOIR FLUID AT 220 F

Molecular composition of liberated gases (mole percent)

Pressure (psig)	3000	2400	1500	600	129	0
Nitrogen	0.87	0.57	0.24	0.00	0.00	0.00
Carbon dioxide	0.65	0.68	0.76	0.86	0.85	0.27
Hydrogen sulphide	0.00	0.00	0.00	0.00	0.00	0.00
<u>Hydrocarbons:</u>						
Methane	80.95	81.87	81.46	74.25	49.23	8.48
Ethane	6.64	6.82	7.55	10.49	15.98	9.34
Propane	4.92	4.92	5.31	7.97	17.44	21.47
I - Butane	0.58	0.56	0.57	0.85	2.13	4.10
N - Butane	2.01	1.94	1.94	2.86	7.46	17.96
I - Pentane	0.63	0.54	0.50	0.69	1.87	6.59
N - Pentane	0.83	0.69	0.62	0.84	2.28	8.91
Hexanes	0.75	0.61	0.49	0.59	1.47	8.42
Heptanes plus	1.17	0.80	0.56	0.60	1.29	14.47
TOTAL	100.00	100.00	100.00	100.00	100.00	100.01
Molecular weight	22.145	21.530	21.359	23.356	31.968	61.253
Gravity (Air=1)	0.764	0.743	0.737	0.806	1.103	2.114
Molecular weight of neptanes plus	107.4	106.2	105.0	104.6	105.8	112.2

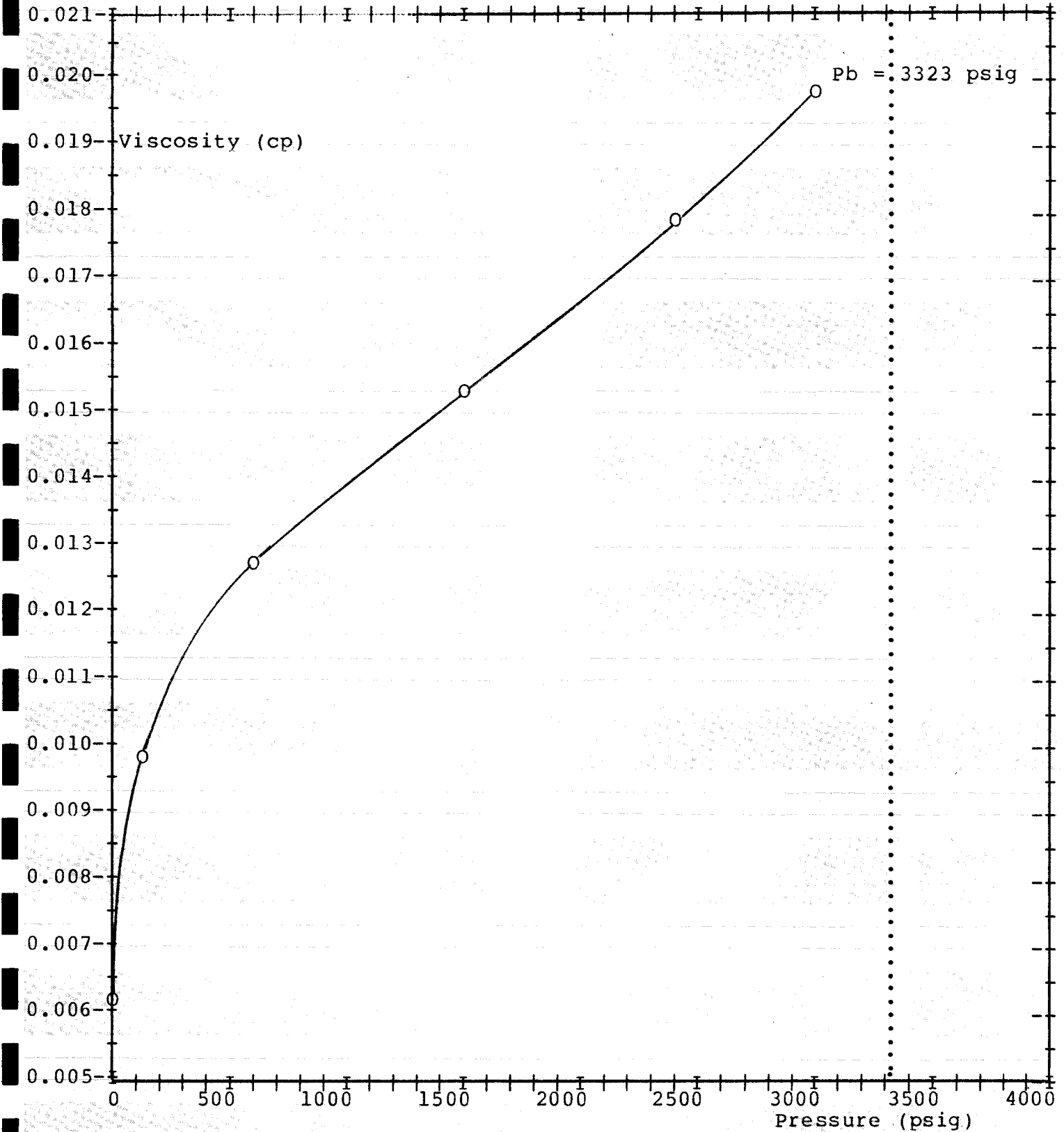
TABLE 9

DIFFERENTIAL VAPORIZATION OF RESERVOIR FLUID AT 220 F

Pressure (psig)	Gas viscosity (centipoises)	Gas gravity (Air=1)	compressibility factor Z
3000	0.0199	0.764	0.856
2400	0.0178	0.743	0.861
1500	0.0153	0.737	0.885
600	0.0127	0.806	0.933
129	0.0098	1.103	0.981
0	0.0061	2.114	1.000

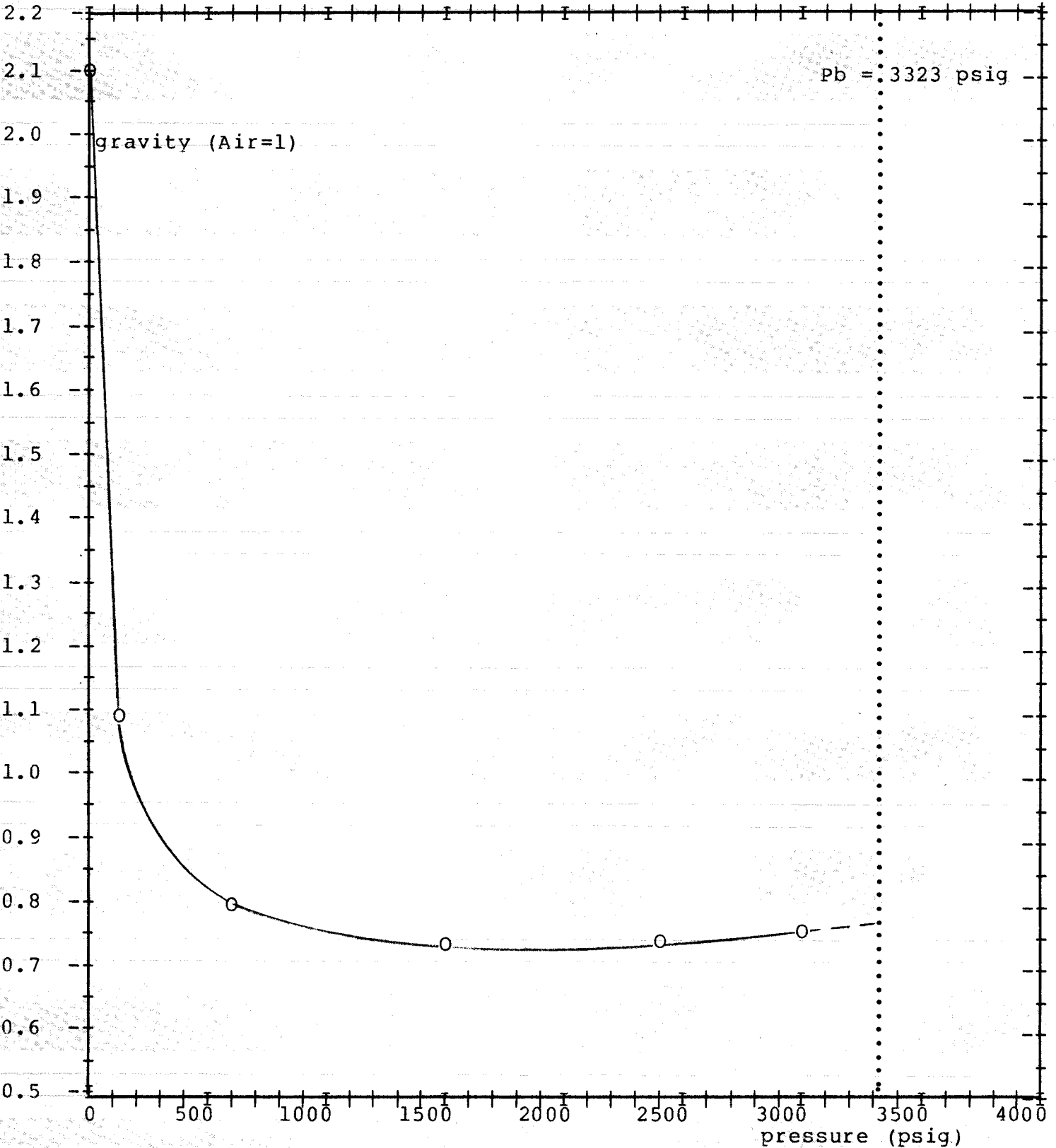
DIFFERENTIAL VAPORIZATION OF RESERVOIR FLUID AT 220 F

liberated gas viscosity



DIFFERENTIAL VAPOORIZATION OF RESERVOIR FLUID AT 220 F

Liberated gas gravity



DIFFERENTIAL VAPORIZATION OF RESERVOIR FLUID AT 220 F

Compressibility factor Z

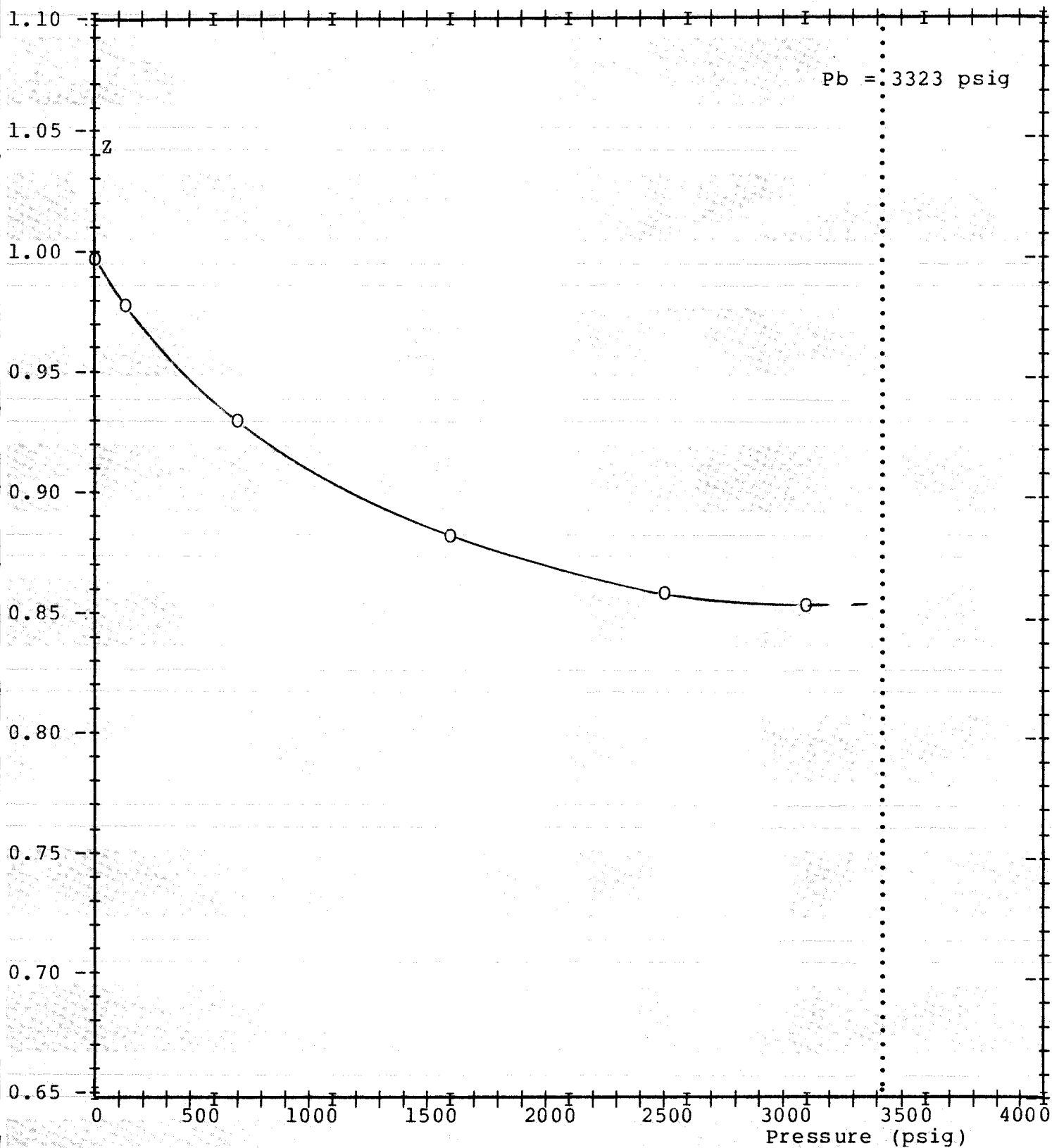


TABLE 10

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/cm3)	Shrinkage factor(3) (Std bbl/bbl)	sto gravity (60/60 F)
Pres. (psig)	Temp. (F)	Sep. Tank	Total				
100	142	789	-	-	0.779	0.908	-
10	160	40	-	-	0.794	0.936	-
0	60	-	7 836	1.468	-	1.000	0.846

(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	0.37	0.00	0.00
Carbon dioxide	0.79	0.78	1.08
Hydrogen sulphide	0.00	0.00	0.00

Hydrocarbons:

Methane	76.55	43.71	18.55
Ethane	9.79	17.47	15.65
Propane	7.44	22.32	31.29
I - Butane	0.78	2.85	5.07
N - Butane	2.53	8.87	17.79
I - Pentane	0.53	1.72	4.21
N - Pentane	0.60	1.49	3.61
Hexanes	0.34	0.44	1.48
Heptanes plus	0.28	0.35	1.27

TOTAL 100.00 100.00 100.00

Molecular weight 22.281 32.329 43.493

Gravity (Air=1) 0.769 1.116 1.501

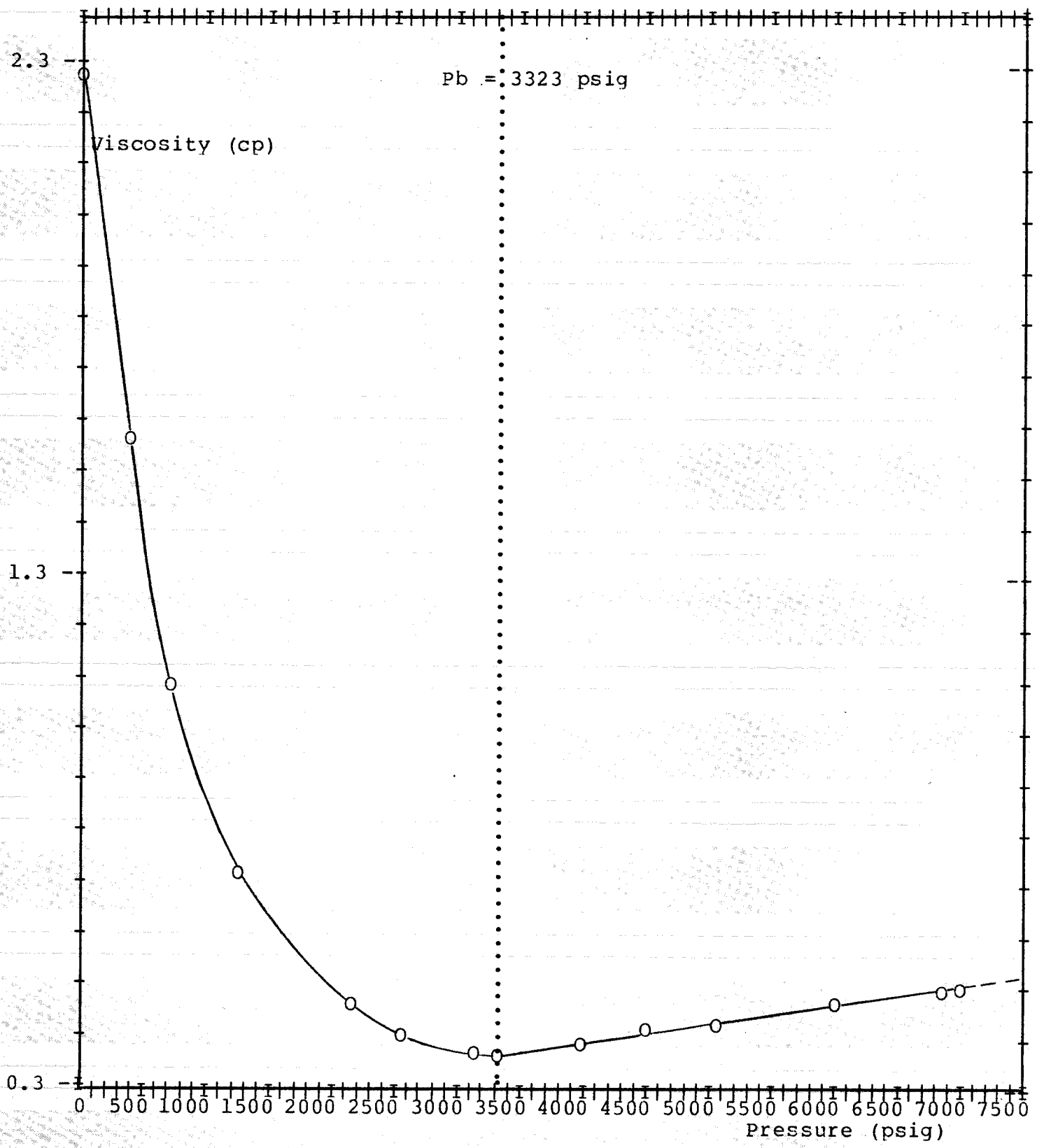
Molecular weight of neptanes plus 104.2 105.8 105.0

TABLE 12

VISCOSITY OF RESERVOIR FLUID AT 220 F

Pressure (psig)	Viscosity (centipoises)
7000	0.50
Pi= 6850	0.49
6000	0.46
5050	0.42
4500	0.41
3980	0.38
Pb= 3323	0.36
3130	0.37
2552	0.41
2150	0.47
1250	0.73
715	1.10
392	1.58
0	2.29

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 : 5.5 psi
Norm ASTM D-323

NOMENCLATURE

- P : Pressure
- V : Volume
- T : Temperature
- Pi : Initial static pressure
- Pb : Bubble point pressure
- Pd : 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
- Bo : Oil formation volume factor
- Rs : Solution gas oil ratio
- Z : Gas compressibility factor or gas deviation factor
- Bg : Gas formation volume factor
- do : Reservoir oil density
- Go : 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)