

Denne rapport
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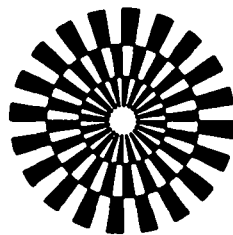
KODE Well 31/2-11 nr 8

Returneres etter bruk

A/S NORSKE SHELL

WELL: 31/2-11

PVT - STUDY



GECO
GEOPHYSICAL COMPANY
OF NORWAY AS



A/S NORSKE SHELL

WELL: 31/2-11

PVT - STUDY



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Reservoir Fluid Study
Well: 31/2-11
Recombined Sample
Bottle no. 22478 (oil)
and no. A 4964 (gas)

S U M M A R Y

This report present the results of a PVT-study of a recombined sample of reservoir fluid from well: 31/2-11.

Separator gas and liquid samples were analysed and recombined according to a GOR of $62.2 \text{ Sm}^3/\text{m}^3$.

Single-stage flash, gas composition, viscosity, differential liberation, pressure-volume relations and separator tests were determined on the recombined sample at 67.8°C .

Main results are:

Bubble point at 67.8°C	:	157.0 barg
Density at bubble point	:	$794.2 \text{ kg}/\text{m}^3$
Compressibility at bubble point:		$1.21 \times 10^{-4} \text{ bar}^{-1}$
Viscosity at bubble point	:	1.545 cp

From single-stage flash:

Gas/oil ratio	:	$66.3 \text{ Sm}^3/\text{m}^3$
B_o at bubble point	:	$1.189 \text{ m}^3/\text{m}^3$
Density of oil at 15°C :		$886.7 \text{ kg}/\text{m}^3$

Standard conditions: for gas volumes = 15°C and 1 atm
for oil volumes = 15°C and atmospheric pressure



SAMPLE

The recombination samples, bottle 22478 (oil) and no. A-4964 (gas) were supplied by A/S NORSKE SHELL and contained fluids sampled from the production separator on well 31/2-11. Separator conditions were 90 psig and 92°F. Opening pressure of separator gas sample at 35°C were 91 psig. Bubble point of separator oil sample was 87 psig at 33.3°C.

LABORATORY PROCEDURE

PVT-analysis

Pressure-volume relations were determined in a Ruska visual liquid PVT cell-oil bath at 67.8°C. Single flash to 15°C and atmospheric pressure and separator tests were performed in a Ruska Flash Separator. Gas volumes were measured by a Ruska Gasometer. Gas samples for analysis were collected in a gas sampling tube (250 ml) connected between the separator and gasometer.

Gas analysis

Gas analysis up to and including nonanes was carried out with a Perkin Elmer Sigma gaschromatograph equipped for automatic gas analysis and column switching. The analysis was carried out isothermally at 65°C with FID and hot wire detector at 150 and 100°C respectively. Columns were 1: 15% squalane on Chromosorb P, 2: Poropak N, 3: Molecular Sieve 5 A.

The C₆₊ fraction is determined by backflushing from column 1 through the FID detector. The separation of the hydrocarbongroups in this fraction is performed in a column filled with 10% SP-2100 on Supelcoport in another P.E. Sigmagaschromatograph, temperature programmed from 40 to 180°C. The determination is done by a FID at 190°C.

The system is calibrated before and after each working day with a calibration gas (Air Products) containing hydrocarbons from methane through pentane, and helium, nitrogen and carbondioxide.

Density and Molecular Weight

Density of stock tank oil was determined at 15°C with an AP Paar Density meter, calibrated with dry air and distilled water before each measurement. Molecular weight was determined by freezing point depression of benzene.



Viscosity

Liquid viscosities were determined with a ROP rolling ball viscosimeter calibrated with viscosity standards from Cannon Instrument Co.

Gas viscosities are calculated from molecular composition according to Lee, A.L., Gonzales, M.H. and Eakin, B.E., J. Petr. Techn. 1966, 977-1000.



FLASH SEPARATION OF SEPARATOR LIQUID
TO STOCK TANK CONDITIONS.

Flash conditions : 100 barg, 33.3°C to atmosphere and 15°C.

Gas oil ratio	: 2.20	sm ³ /m ³
Gas gravity	: 0.984	
Bo at 100 barg	: 1.026	
Bo at bubble point	: 1.033	
Density of oil at 15°C	: 885.1	kg/m ³ 28.37 °API
Density of separator liquid at bubble point	: 859.4	kg/m ³
Molecular weight of oil	: 233	
Molecular weight of C ₁₀ ⁺ (calculated)	: 294	

Separator gas properties calculated from molecular composition.

Gas gravity (air = 1)	: 0.679
Compressibility factor	: 0.9836

MOLECULAR COMPOSITION OF SEPARATOR LIQUID, SEPARATOR
GAS AND MATHEMATICALLY RECOMBINED RESERVOIR FLUID.

Component	Stock tank oil (mol %)	Gas from separator liq. (mol %)	Recombined separator liq. (mol %)	Separator gas (mol %)	Recombined reservoir fluid (mol %)
Nitrogen		0.27	0.01	0.65	0.27
Carbon dioxide		3.14	0.07	1.66	0.71
Methane		51.14	1.22	85.45	35.19
Ethane	0.43	24.95	1.02	7.80	3.76
Propane	0.94	9.67	1.15	1.85	1.43
iso-Butane	1.55	4.35	1.62	1.00	1.37
n-Butane	0.62	2.86	0.68	0.30	0.52
iso-Pentane	1.69	1.39	1.68	0.35	1.15
n-Pentane	0.31	1.05	0.33	0.06	0.22
Hexanes	4.99	0.61	4.88	0.42	3.08
Heptanes	11.85	0.40	11.58	0.40	7.07
Octanes	5.06	0.13	4.94	0.05	2.97
Nonanes	3.35	0.04	3.27	0.01	1.95
Decanes plus	69.21	0.00	67.55	0.00	40.32





FLASH OF RECOMBINED RESERVOIR FLUID TO STOCK TANK CONDITIONS

Flash conditions : 300 barg, 67.8°C to atmosphere and 15°C.

Gas oil ratio	: 66.3	sm ³ /m ³
Bo at 300 barg	: 1.171	m ³ /m ³
Bo at bubble point	: 1.189	m ³ /m ³
Density of oil at 15°C	: 886.7	kg/m ³ , 28.08 °API
Density at bubble point	: 794.2	kg/m ³
Molecular weight of oil	: 236	
Gas gravity (air=1)	: 0.679	
Molecular weight of C ₁₀ + (calculated)	: 285	



FLASH OF RECOMBINED RESERVOIR LIQUID TO STOCK TANK CONDITIONS.
 MOLECULAR COMPOSITION OF RECOMBINED RESERVOIR FLUID.

Component	Stock tank oil (mol %)	Separator gas (mol %)	Recombined reservoir fluid (mol %)
Nitrogen		0.74	0.32
Carbon dioxide		1.64	0.70
Methane		83.07	35.49
Ethane	0.08	8.39	3.63
Propane	0.30	2.44	1.21
iso-Butane	0.68	1.49	1.03
n-Butane	0.34	0.48	0.40
iso-Pentane	1.16	0.58	0.91
n-Pentane	0.23	0.11	0.18
Hexanes	4.65	0.29	2.78
Heptanes	11.16	0.76	6.72
Octanes	5.41	0.01	3.10
Nonanes	2.26	0.00	1.30
Decanes plus	73.73	0.00	42.23



PRESSURE-VOLUME RELATION AT CONSTANT MASS OF RECOMBINED
RESERVOIR LIQUID AT 67.8°C.

Pressure bar gauge	Relative volume V/V _{sat}	Isothermal compressibility bar ⁻¹	"γ"
300.6	0.9847	0.94·10 ⁻⁴	
274.5	0.9871	0.99·10 ⁻⁴	
250.8	0.9895	1.03·10 ⁻⁴	
226.9	0.9919	1.08·10 ⁻⁴	
203.9	0.9948	1.12·10 ⁻⁴	
176.1	0.9976	1.17·10 ⁻⁴	
157.0	1.0000	1.21·10 ⁻⁴	
128.5	1.0573		3.872
103.1	1.1461		3.580
77.3	1.3113		3.312
54.6	1.6066		3.092



DIFFERENTIAL LIBERATION OF RESERVOIR FLUID AT 67.8°C

Pressure (barg)	Oil Formation Volume Factor B_o (m^3/m^3)	Solution gas oil ratio R_s (Sm^3/m^3)	Gas Formation Volume Factor B_g (m^3/Sm^3)	Density of sat oil (kg/m^3)
300.6	1.166			804.3
274.5	1.169			802.4
250.8	1.172			800.4
226.9	1.174			798.5
203.9	1.178			796.1
176.1	1.181			793.9
157.0	1.184	63.4		792.0 *)
133.5	1.164	53.7	7.79×10^{-3}	799.2
109.6	1.147	45.1	9.56×10^{-3}	805.2
82.2	1.126	34.5	13.03×10^{-3}	813.0
53.4	1.104	23.6	20.43×10^{-3}	821.6
32.4	1.088	15.4	34.08×10^{-3}	827.7
17.9	1.074	9.3	60.65×10^{-3}	833.9
0	1.047			845.8

Residual oil density at 15°C : 885.1 kg/m^3

*) Density at bubble point from single flash: 794.4 kg/m^3

DIFFERENTIAL LIBERATION OF RECOMBINED RESERVOIR FLUID AT 67.8°C

MOLECULAR COMPOSITION OF LIBERATED GASES (MOL. %)

Pressure/barg:	133.5	109.6	82.2	53.4	32.4	17.9	0
Nitrogen	1.64	1.22	0.87	0.52	0.36	0.17	0.00
Carbon dioxide	1.13	1.18	1.29	1.48	1.73	2.10	2.90
Methane	91.63	91.93	91.76	90.86	88.75	85.15	55.50
Ethane	3.49	3.71	4.17	5.08	6.64	9.02	25.07
Propane	0.64	0.66	0.72	0.87	1.15	1.69	8.64
iso-Butane	0.32	0.32	0.33	0.39	0.51	0.75	4.57
n-Butane	0.10	0.09	0.10	0.12	0.14	0.20	1.19
iso-Pentane	0.13	0.12	0.11	0.12	0.15	0.21	1.08
n-Pentane	0.02	0.02	0.02	0.02	0.03	0.04	0.16
Hexanes	0.14	0.11	0.10	0.09	0.12	0.15	0.43
Heptanes	0.63	0.52	0.38	0.30	0.34	0.42	0.39
Octanes	0.13	0.12	0.14	0.13	0.07	0.09	0.07
Nonanes	0.00	0.00	0.01	0.01	0.01	0.01	0.00
Decanes-plus	0.00	0.00	0.00	0.01	0.00	0.00	0.00





DIFFERENTIAL LIBERATION OF RECOMBINED FLUID AT 67.8°C

(Gas properties calculated from molecular composition)

Pressure (barg)	Gas viscosity (cP)	Gas Gravity (Air=1)	Compressibility factor, Z
133.5	0.0161	0.630	0.8678
109.6	0.0152	0.625	0.8791
82.2	0.0143	0.624	0.8992
53.4	0.0136	0.629	0.9277
32.4	0.0131	0.644	0.9521
17.9	0.0127	0.673	0.9705
0	0.0114	0.919	0.9975



VISCOSITY OF RECOMBINED FLUID AT 67.8°C

Pressure (barg)	Viscosity (centipoise)
306.6	1.814
276.2	1.758
250.3	1.721
225.2	1.682
200.0	1.625
178.0	1.580
150.9	1.750
127.8	1.891
104.1	2.138
77.1	2.397
50.6	2.723

SEPARATOR TESTS OF RECOMBINED FLUID AT DIFFERENT PRESSURES
AND AMBIENT TEMPERATURE

Separator conditions		Separator gas oil ratio sm^3/m^3	Bo m^3/m^3	Density of oil at 15°C kg/m^3	Gas gravity Air=1
Pressure	Temperature				
300 psig	20°C	64.8	1.162	885.5	0.658
200 psig	20°C	65.2	1.172	884.7	0.618
100 psig	20°C	63.5	1.178	885.8	0.629
50 psig	20°C	65.4	1.185	885.9	0.654
0 psig	15°C	66.3	1.189	886.7	0.679



SEPARATOR TESTS OF RECOMBINED FLUID AT DIFFERENT PRESSURES AND AMBIENT TEMPERATURE.

Molecular composition of liberated gases (Mol %)

Sep. pressure	300 psig	200 psig	100 psig	50 psig
Nitrogen	1.11	1.03	0.89	0.79
Carbon dioxide	1.59	1.44	1.53	1.63
Methane	87.22	90.71	89.37	86.72
Ethane	6.67	5.36	6.25	7.59
Propane	1.49	0.80	1.07	1.69
iso-Butane	0.63	0.30	0.44	0.80
n-Butane	0.35	0.09	0.13	0.25
iso-Pentane	0.23	0.08	0.11	0.21
n-Pentane	0.13	0.02	0.02	0.05
Hexanes	0.10	0.03	0.04	0.10
Heptanes	0.46	0.13	0.14	0.15
Octanes	0.02	0.01	0.01	0.02
Nonanes	0.00	0.00	0.00	0.00
Decanes plus	0.00	0.00	0.00	0.00



FIG. 1

PRESSURE-VOLUME RELATIONS OF
RECOMBINED LIQUID AT 67.8 °C

$P_b = 157.0$ barg

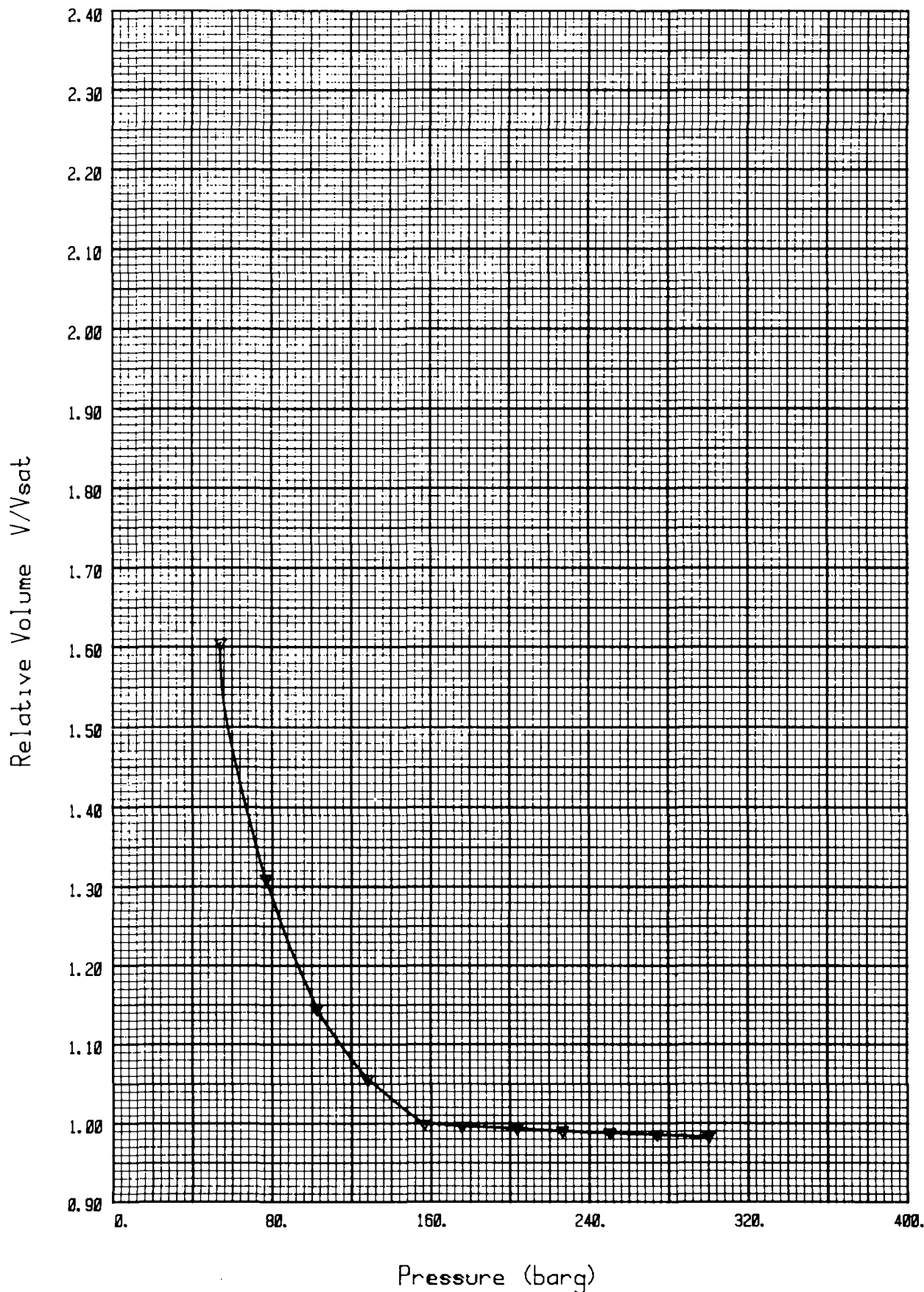


FIG. 2

DIFFERENTIAL LIBERATION AT 67.8 °C
OIL FORMATION VOLUME FACTOR

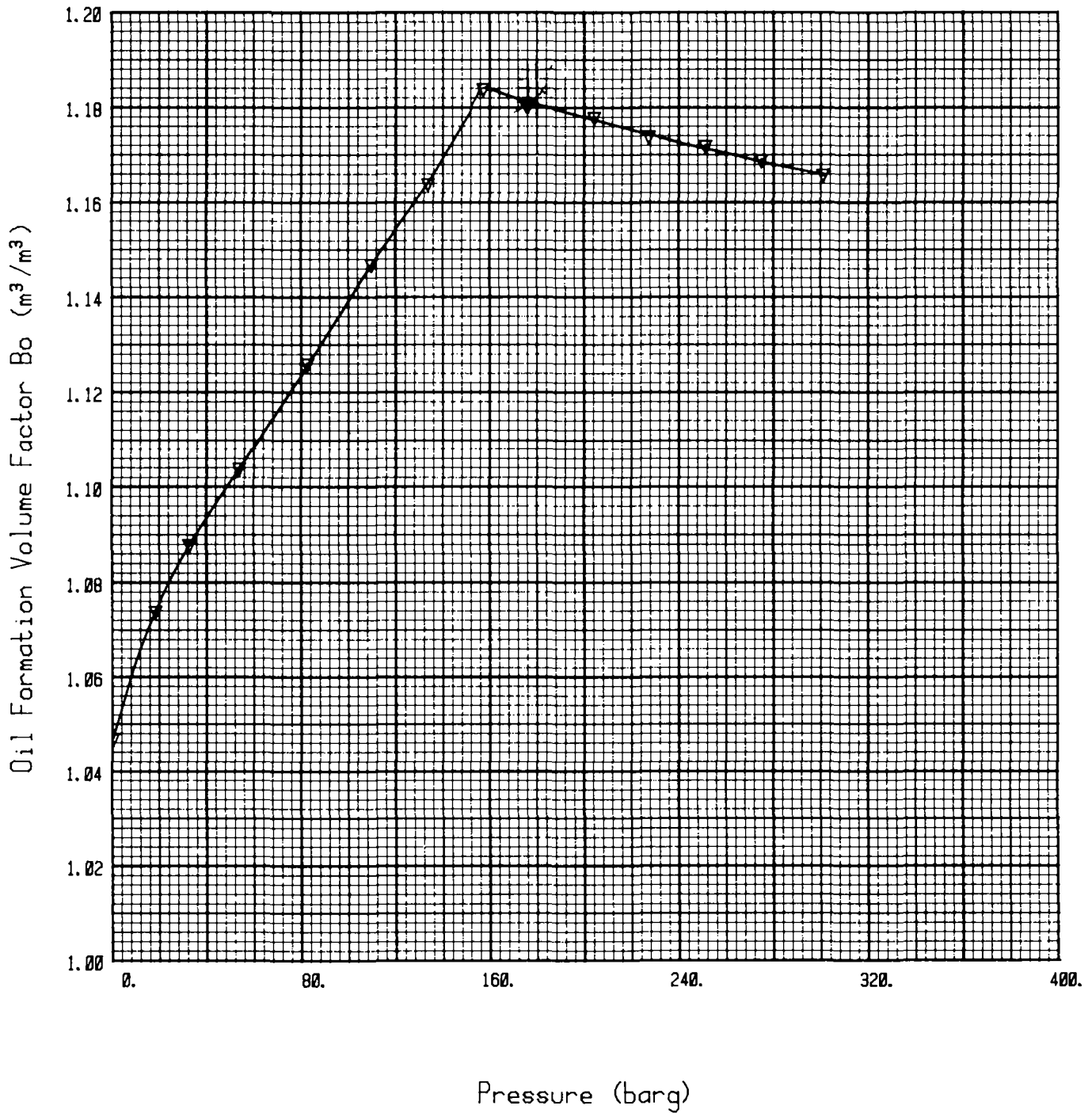


FIG. 3

DIFFERENTIAL LIBERATION AT 67.8 °C
SOLUTION GAS-OIL RATIO

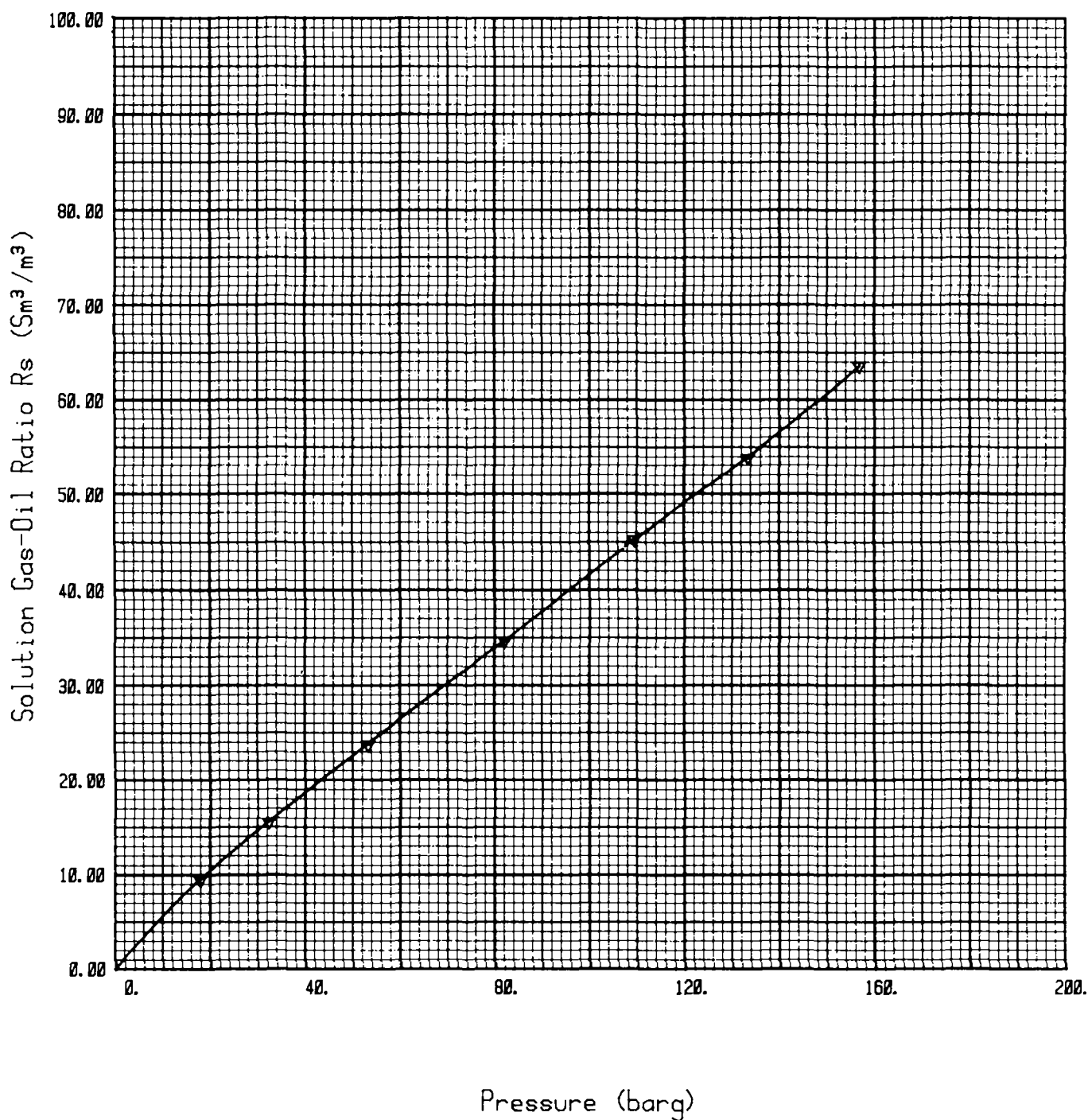


FIG. 4

DIFFERENTIAL LIBERATION AT 67.8 °C
GAS FORMATION VOLUME FACTOR

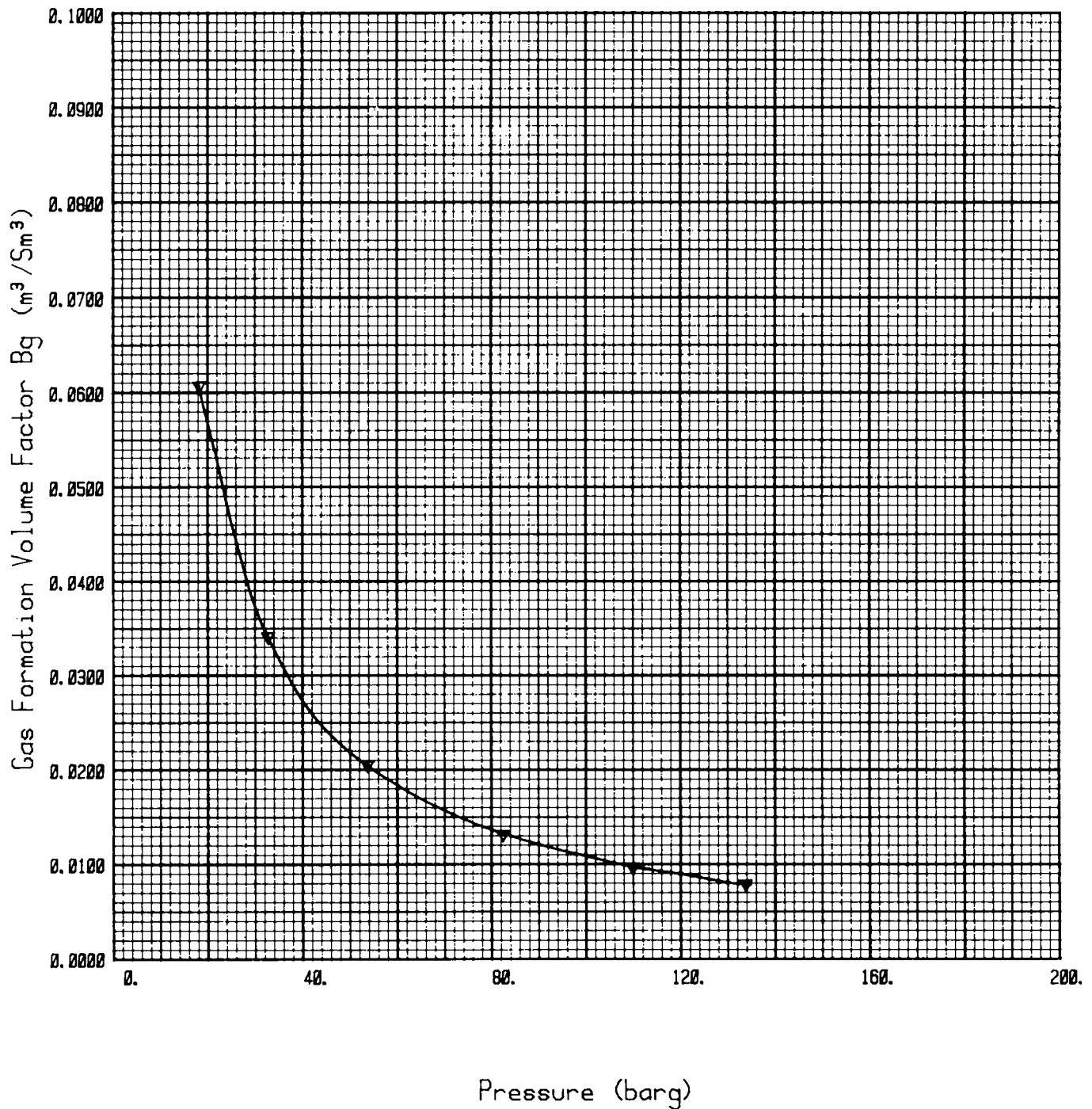


FIG. 5

DIFFERENTIAL LIBERATION AT 67.8 °C
LIBERATED GAS VISCOSITY

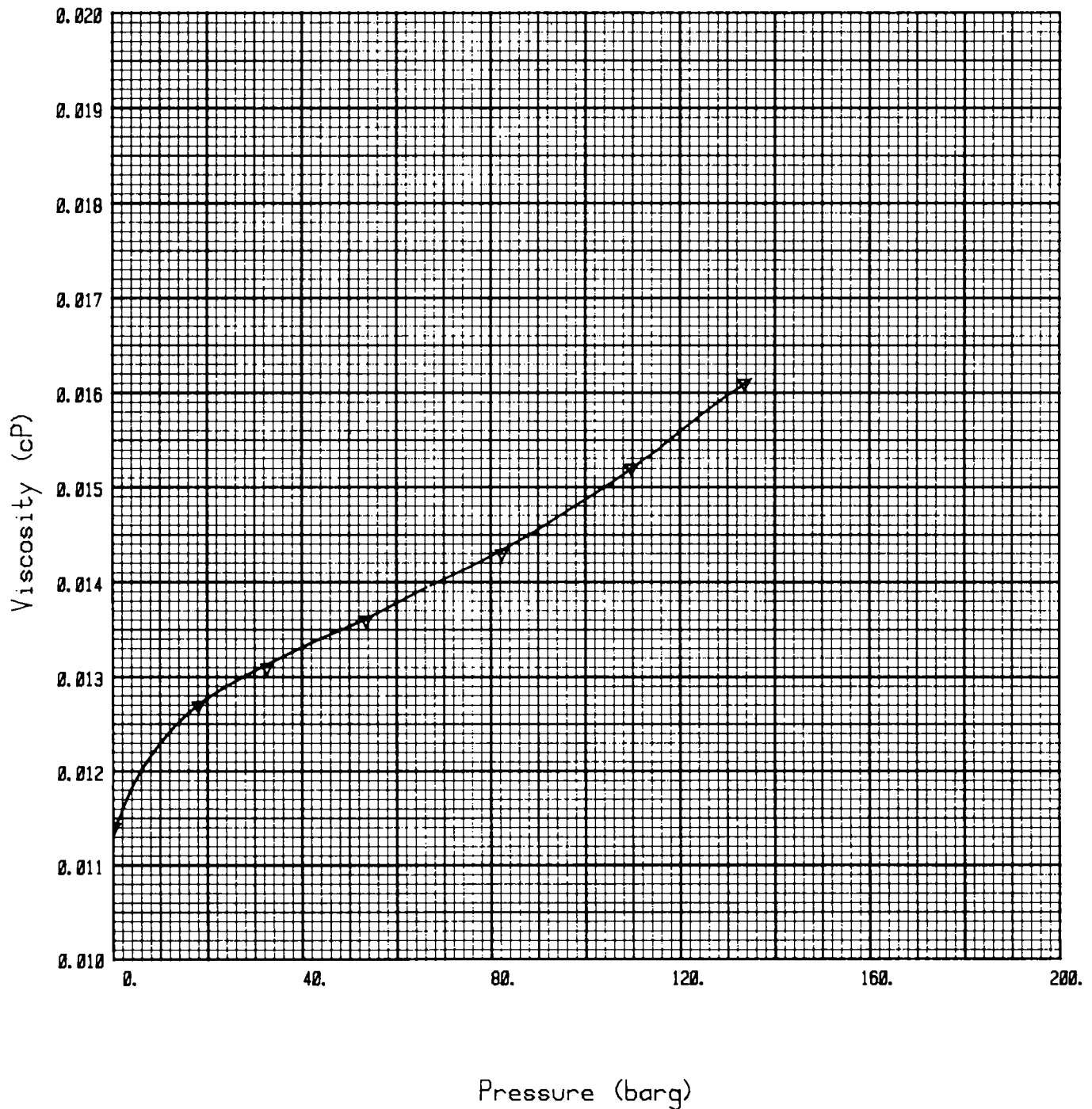


FIG. 6

DIFFERENTIAL LIBERATION AT 67.8°C
LIBERATED GAS GRAVITY

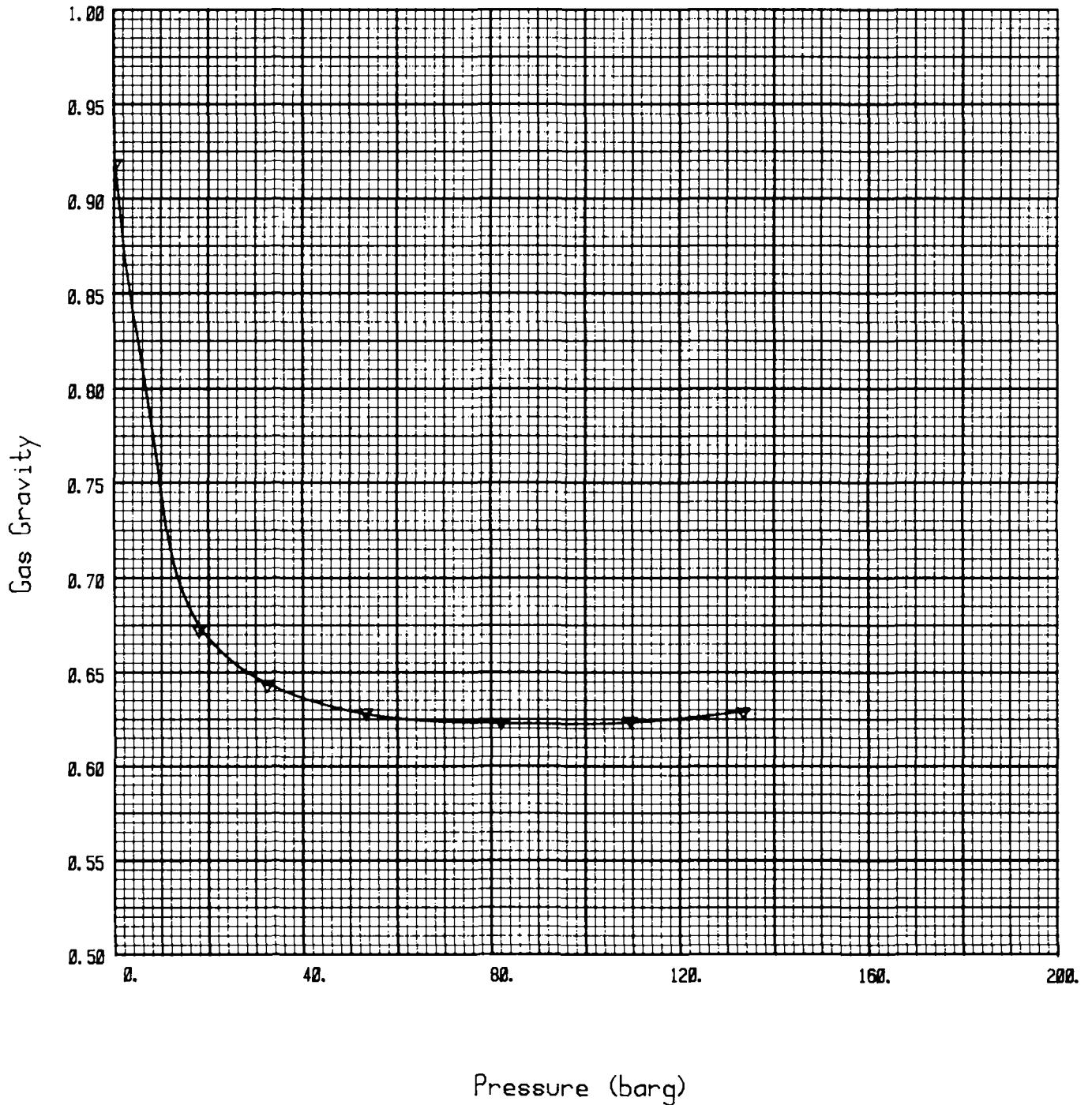


FIG. 7

VISCOSITY OF RECOMBINED LIQUID AT 67.8 °C

