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GAS - A COMPUTER PROGRAM TO PREDICT GAS WELL DELIVERABILITY

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CONTENTS

INTRODUCTION

The purpose of this computer program is to calculate the flow of gas and condensate against a minimum surface pressure with a minimum of input data.

DISCUSSION

The ability to analyse the performance and forecast the productivity of gas wells (deliverability) with a reasonable degree of accuracy is of utmost importance in assessing Australia's natural gas reserves.

Since the calculation of deliverability has become important to the Reservoir Engineering Sub-section and very time-consuming (it took 4-man weeks of analysis per reservoir) it was decided to computerise our approach. The in-house Hewlett-Packard 2100 computer has proved very satisfactory for this purpose. The final large storage capacity required in the computer for the running of the program necessitated segmenting the program into 3 sections.

The first segment which sets up a large 'COMMON' storage block calls the second segment which calculates the gas deviation factor and the viscosity from the gas composition. Then it calculates the gas potential and calls for the third segment. This third segment calculates Darcy and non-Darcy flow in the reservoir and flow in the tubing.

This program uses the latest published algorithm for obtaining the gas deviation factor. This gas deviation factor expresses the departure of real gases from the idealized behaviour of gases as predicted by Boyle's and Charle's Law.

Interpolation procedure is still required in the determination of gas viscosity at reservoir conditions since no algorithm expressing viscosity as a function of pressure, temperature, and gas composition has been published. In this case there are 246 data points which form the basis of the interpolation procedure. In both the gas deviation and viscosity determinations, correction factors for hydrogen sulphide, carbon dioxide, and nitrogen have been incorporated.

The deliverability calculations proper are based on recent mathematical developments (Energy Resources Conservation Board, 1975) which utilize the gas-potential (or 'pseudo-pressure function') approach preparing an array of gas potential data versus pressure. This part of the program also incorporates a subroutine which uses input from PVT (pressure, volume, temperature) analyses. With this the changing fluid composition during the life of a field (i.e. versus reservoir pressure) can be closely predicted.

The important constraints which govern the amount of gas a field can deliver into a pipeline are intrinsic or extrinsic. Important intrinsic constraints to be considered are:

(a) gas initially in place and its quality
(b) permeability and thickness of the reservoir
(c) skin factor (formation damage adjacent to well bore causing reduced permeability)
(d) non-Darcy flow (or turbulence).

Five important extrinsic constraints considered in the program GAS are:

(a) tubing diameter
(b) number of producing wells
(c) initial raw gas production rate
(d) minimum tubing head pressure (at the surface)
(e) minimum (or cut-off) production rate (which is related to the economics of the field).

Out of the large number of possible constraints available, the engineer selects the appropriate set of factors for individual fields.

Special notice should be given for the appreciation the authors have for help given to them by the Operations Branch (ADP Section) in particular Mrs Fay Newman for Fortran coding advice, to Warren de Courcy Browne for the numerous debugging runs, and to Bob Moore for advice on Gould plotting software.

TERMINOLOGY AND DESCRIPTION OF SUBROUTINES

This section briefly describes and/or references the important parameters derived and used in the gas deliverability program.

1) Average Molecular Weight

The average molecular weight is calculated by multiplying the mole fraction of the well stream gas by the respective molecular weights (Katz et al., 1959).

2) Sales Gas

Sales gas is here defined to include all the methane and ethane, and up to 3% carbon dioxide (arbitrary limit assumed). It is reported as a fraction of the raw (or well stream) gas.

3) Gas Gravity

The gas gravity is the ratio of the molecular weight of the gas to that of air (28.966).

4) Dry-Basis Heating Value (Sales Gas)

The heating value of natural gas is the heat liberated when a unit of fuel is burned under specified conditions.

Methane and ethane have heating values of 1012 and 1783 BTU/cubic ft respectively at 14.7 psia and 60°F (Katz et al., 1959 p.160).

5) LPG and Condensate Gas Ratios

LPG is here defined as propane and butanes fraction. Condensate is taken to include the pentanes, hexanes, and heptanes plus fraction. The ratio is reported as barrels per million standard cubic feet of raw gas, and in metric as cubic metres per million cubic metres (at initial reservoir conditions). Subroutine GPM calculates the changing LPG and Condensate/Gas Ratios with decreasing reservoir pressure. It is based on pressure, volume, and temperature (PVT) data gathered in the laboratory.

6) Gas Deviation Factor (Subroutine ZSTAR)

Gas deviation factors are calculated from an 11 parameter equation of state, developed by Dranchuk & Abou-Kassem (1975). The equation effectively reproduces the Standing-Katz gas deviation factor charts. The subroutine incorporates a correction for the presence of hydrogen sulphide and carbon dioxide by the method of Wichert & Aziz (1972). Gas compressibilities are calculated by the method of Mattar, Brar, & Aziz (1975). The differentiated form of the Dranchuk & Abou-Kassem equation is the basis of the compressibility expression.

7) Viscosity (Subroutine VISCY)

This subroutine is based on that published by the Canadian Energy Resources Conservation Board (1975). This subroutine determines the viscosity for natural gas incorporating a correction for the presence of hydrogen sulphide, carbon dioxide, and nitrogen.

8) Gas Potential

The gas potential for various reservoir pressures is calculated by the method of Al-Hussainy & Ramey (1966), Al-Hussainy et al (1966), and is used to predict more precisely the depletion behaviour of low-permeability reservoirs.

9) Gas Flow Calculations

The raw gas production rate in MMCF/D is converted to an annual flow and year end pressures are calculated from the material balance. The Darcy and non-Darcy flow are used to calculate flowing bottom-hole pressures.

The flowing tubing head pressure is calculated using the R.V. Smith-modified Weymouth equations. These formulae, rearranged, are shown diagrammatically in Figure 1.

The production rate is reduced by 2% and the above calculations are redone if any one of three conditions exist:

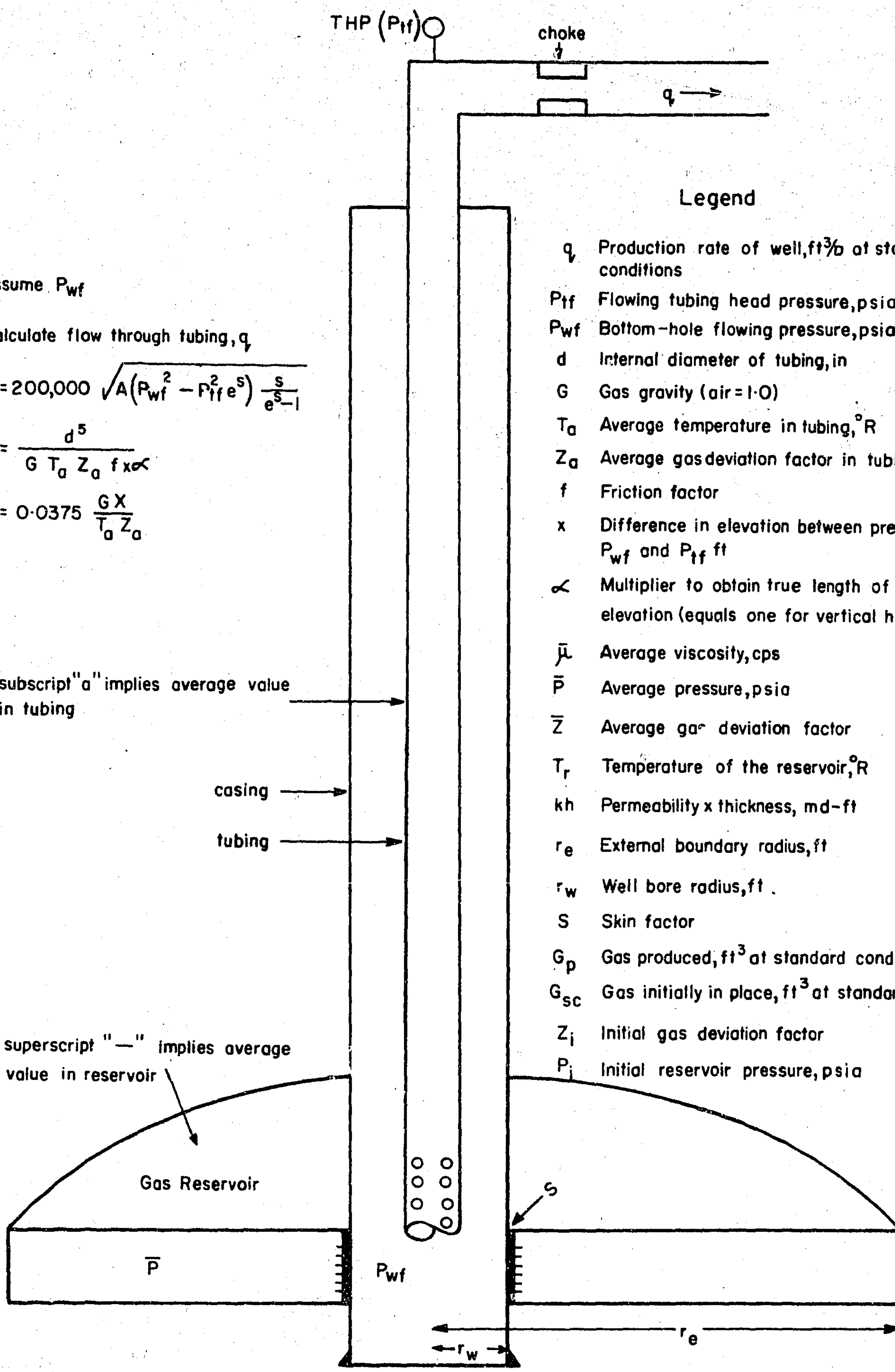
(1) Flowing pressure (bottom hole) is less than zero.
(2) Flowing surface pressure (tubing head) is less than zero.
(3) Flowing surface (tubing head) pressure is less than the minimum supplied in the input data.

If the wet gas flow rate, Q, is less than 0.98 of the minimum rate of production, Q is set to zero for the remaining years.

The results by years are stored in arrays for printing and plotting.

GAS FLOW EQUATIONS

Fig. 1



① Assume P_{wf}

calculate flow through tubing, q

$$q = 200{,}000\sqrt{A\left(P_{wf}^2 - P_{tf}^2 e^S\right)\frac{S}{e^S - 1}}$$

$$\text{where } A = \frac{d^5}{G\, T_a\, Z_a\, f\, x\, \alpha}$$

$$s = 0{\cdot}0375\,\frac{G X}{T_a Z_a}$$

Legend

q	Production rate of well, ft³/D at standard conditions
P_{tf}	Flowing tubing head pressure, psia
P_{wf}	Bottom-hole flowing pressure, psia
d	Internal diameter of tubing, in
G	Gas gravity (air = 1·0)
T_a	Average temperature in tubing, °R
Z_a	Average gas deviation factor in tubing
f	Friction factor
x	Difference in elevation between pressures P_{wf} and P_{tf} ft
α	Multiplier to obtain true length of tubing from elevation (equals one for vertical hole)
$\overline{\mu}$	Average viscosity, cps
$\overline{P}$	Average pressure, psia
$\overline{Z}$	Average ga^ deviation factor
T_r	Temperature of the reservoir, °R
kh	Permeability x thickness, md-ft
r_e	External boundary radius, ft
r_w	Well bore radius, ft.
S	Skin factor
G_p	Gas produced, ft³ at standard conditions
G_{sc}	Gas initially in place, ft³ at standard conditions
Z_i	Initial gas deviation factor
P_i	Initial reservoir pressure, psia

② Assume same P_{wf} as above

calculate average reservoir pressure, $\overline{P}$:

$$\overline{P} = \sqrt{P_{wf}^2 + C_4\, q\, \overline{\mu}\, \overline{z}}$$

$$\text{where } C_4 = 3{\cdot}28\,\frac{T_r}{kh}\left[\log\frac{r_e}{r_w} - 0{\cdot}326 + 0{\cdot}434\,S + Dq\right]$$

$$Gp = Gsc\left(1 - \frac{Z_i}{P_i}\,\frac{\overline{P}}{\overline{Z}}\right)$$

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MODIFICATION No. I

the equation :

$$\bar{P} = \sqrt{P_{wf}^2 + C_4 q \bar{\mu} \bar{z}}$$

is modified to :

$$\bar{\Phi} = \Phi_{wf} + C_4 q$$

where :

$$\phi = \int_0^p \frac{2p}{\mu z} \, dp$$

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APPENDIX I

DATA INPUT

DATA INPUT

LINE/ CARD		
1	TITLE (UP TO 40 CHARACTERS).	
2	RUN (NUMBER),	DATE (hyphenated), LUN,ICODE,KPMAX,IPL (no commas, no spaces, 000109-06-773011)
		LUN = 3 or any other number except 6 does not write debug statements
		= 6 writes debug values
		ICODE = 0 uses entire program
		= 1 aborts program after p vs μ, z are calculated
		KPMAX = 0 no PVT data available
		= 1 to 9 LPG and Cond calculated allowing for retrograde condensation
		IPL = 0 no plotting
		= 1 use plot routines
3	MFC 1, MFC 2, MFC 3, MFC4I, MFC4N, MFC5I, MFC5N, MFC6, MFC7P, MFH2S, MFCO2, MFN2.	

MFC 1	MOLE fraction methane	measured compositions at reservoir pressure and temperature	
MFC 2	" " ethane		
MFC 3	" " propane		
MFC4I	" " iso-butane		
MFC4N	" " n - butane		
MFC5I	" " iso-pentane		
MFC5N	" " n-pentane		
MFC6	" " hexanes		
MFC7	" " hexanes plus		
MFH_2S	" " hydrogen sulphide		
$MFCO_2$	" " carbon dioxide		
MFN_2	" " nitrogen		

<u>Note</u>: MFC 3 and MFC 5I must not be zero for program to operate; therefore insert 0.00001 if these components are reported to be zero quantity.

4 P, T: initial reservoir Pressure (p.s.i.a.), Temperature (^{o}F)

Subroutine GPM (Line)

<u>For KPMAX equals any number up to 9</u>

4A	PAI (KPMAX)	PAI (2), PAI (1)
	Pressure points of PVT data (psia) (Highest Pressure first).	
4B	C3P (KPMAX)	C3P(2), C3P(1)
	Corresponding Bbls. per MMCF of C3 plus C4, **Cumulative Recovery**	
4C	C5P (KPMAX)	C5P (2), C5P (1)
	Corresponding Bbls. per MMCF of C5 plus , **Cumulative Recovery**	

DATA INPUT

5 VOL, POR, SATW, AVETH

	VOL:	volume of gas initially in place (MMSCF) (wet gas)
	POR:	porosity (fraction)
	SATW:	water saturation (fraction)
	AVETH:	average thickness (feet)

6 NYRMAX, NW, MAR

	NYRMAX:	maximum no. of years of projection: (16, 24 or 40 are optimum NYRMAX)
	NW:	no of producing wells
	MAR:	market data by years provided: MAR = 1, otherwise MAR = 0
6A	QMAR:	market requirements by years (MMCF/DAY) (free format) start with year 1 continue to NYRMAX

DATA INPUT

7 RW, KH, S, DTURB

RW	well radius (feet)
KH	permeability - thickness (md. ft.)
S	skin factor (dimensionless)
DTURB	turbulence factor $(MMCF/D)^{-1}$

8 Q, QMIN, THPMIN, QOVER

Q	assumed wet gas production rate per well, average (MMSCF/D)
QMIN	" minimum wet gas production rate per well (MMSCF/D)
THPMIN	assumed minimum tubing pressure (psia)
QOVER	ratio, peak to average gross gas production rate

9 TBGEL, TBGDIA, FR, FAC, TEMPTOP, IEND

TBGEL	tubing length, TVD (feet)
TBGDIA	tubing inside diameter (inches)
FR	(4 times Fanning Friction Factor) friction factor (dimensionless)
FAC	ratio, tubing actual length to TVD
TEMTOP	temperature at tubing head (deg. F)
IEND	set to -1 or else data is in error

```
OLD1   T=00003 IS ON CR00009 USING 00001 BLKS R=0000

 OLD FIELD
002410-10-773001
.85,.04,.015,.012,.012,.011,.011,.023,.026,.0,.0,.0
5000.0,200.0
10000000.0,0.20,0.20,300.0
24,25,0
0.5,5000.0,20.0,0.0
50.0,5.0,1215.0,1.2
10000.0,4.5,0.014,1.1,160.0,-1
```

	TITLE											
1												
	RUN	DATE = CODE										
2												
	C1	C2	C3	IC4	NC4	IC5	NC5	C6	C7+	H_2S	CO_2	N_2
3												
	PRESS	TEMP										
4				(PVT DATA)								
	PA1 (KPMAX)											
4A												
	C3P (KPMAX)											
4B												
	C5P (KPMAX)											
4C												

Notes:

Appendix 1

TITLE ____________________ RUN ______ DATE ______

Card	VOL	POR	SATW	AVETH
5				

Card	NYRMAX	NW	MAR
6			0

Card	QMAR →											
6A												

Card	QMAR →											
6B												

Card	QMAR →											
6C												

Card	RW	KH	S	DTURB
7				

Card	Q	QMIN	THPMIN	QOVER
8				

Card	TBGEL	TBGDIA	FR	FAC	TEMTOP	IEND
9						−1

Notes :

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APPENDIX 2

DATA OUTPUT

DELIVERABILITY PARAMETERS

RESERVOIR DATA

VOLUME OF GAS INITIALLY IN PLACE	10000000.	(MMSCF)
POROSITY	.2000	(FRACTION)
WATER SATURATION	.2000	(FRACTION)
AVERAGE THICKNESS OF RESERVOIR	300.0000	(FT)
INITIAL RESERVOIR TEMPERATURE	200.	(DEGREES F)
INITIAL RESERVOIR PRESSURE	5000.	(PSIA)

WELL DATA

WELL RADIUS	.5000	(FT)
PERMEABILITY*THICKNESS	5000.0000	(MDS-FT)
SKIN FACTOR	20.00	
TURBULENCE FACTOR	.0000	(D/MMSCF)
TUBING ELEVATION (TRUE VERTICAL DEPTH)	10000.	(FT)
TUBING DIAMETER	4.5000	(IN)
FRICTION FACTOR	.0140	
ACTUAL LENGTH / TRUE VERTICAL DEPTH FACTOR	1.1000	
TEMPERATURE OF GAS AT SURFACE IN TUBING	160.	(DEGREES F)

ASSUMED REQUIREMENTS

INITIAL RAW GAS PRODUCTION RATE	50.0000	(MMSCF/D/WELL)
NUMBER OF PRODUCING WELLS	25	
PEAK PRODUCTION RATE / PRODUCTION RATE	1.2000	(RATIO)
MINIMUM TUBING HEAD PRESSURE	1215.	(PSIA)
MINIMUM (OR CUT-OFF) PRODUCTION RATE	5.0000	(MMSCF/D/WELL)

DEFINITIONS

SALES GAS - METHANE, ETHANE, AND UP TO 3% CARBON DIOXIDE
LPG - PROPANE AND BUTANES
CONDENSATE - PENTANES PLUS

COMPONENTS	MOLECULAR WEIGHT	CRITICAL PRESSURE (PSIA)	CRITICAL TEMPERATURE (R)	MOL FRACTION
METHANE	16.042	673.1	343.2	.85000
ETHANE	30.068	708.3	549.8	.04000
PROPANE	44.094	617.4	665.9	.01500
ISO-BUTANE	58.120	529.1	734.6	.01200
N-BUTANE	58.120	550.7	765.3	.01200
ISO-PENTANE	72.146	483.0	829.7	.01100
N-PENTANE	72.146	489.5	845.6	.01100
HEXANES	86.172	439.7	914.2	.02300
HEPTANES PLUS	114.22	362.1	1024.9	.02600
HYDROGEN SULPHIDE	34.076	1306.0	672.4	.00000
CARBON DIOXIDE	44.010	1073.0	547.7	.00000
NITROGEN	28.016	492.0	226.9	.00000
		AVERAGE 652.91	AVERAGE 407.80	TOTAL 1.00000

AVERAGE MOLECULAR WEIGHT OF GAS = 23.43 GAS GRAVITY = .809

SALES GAS = .8900 MMSCF/MMSCF RAW GAS

DRY-BASIS HEATING VALUE = 1047. BTU/CUBIC FOOT VAPOR AT 14.696 PSIA,
(.38997E+08 JOULE/CUBIC METRE)

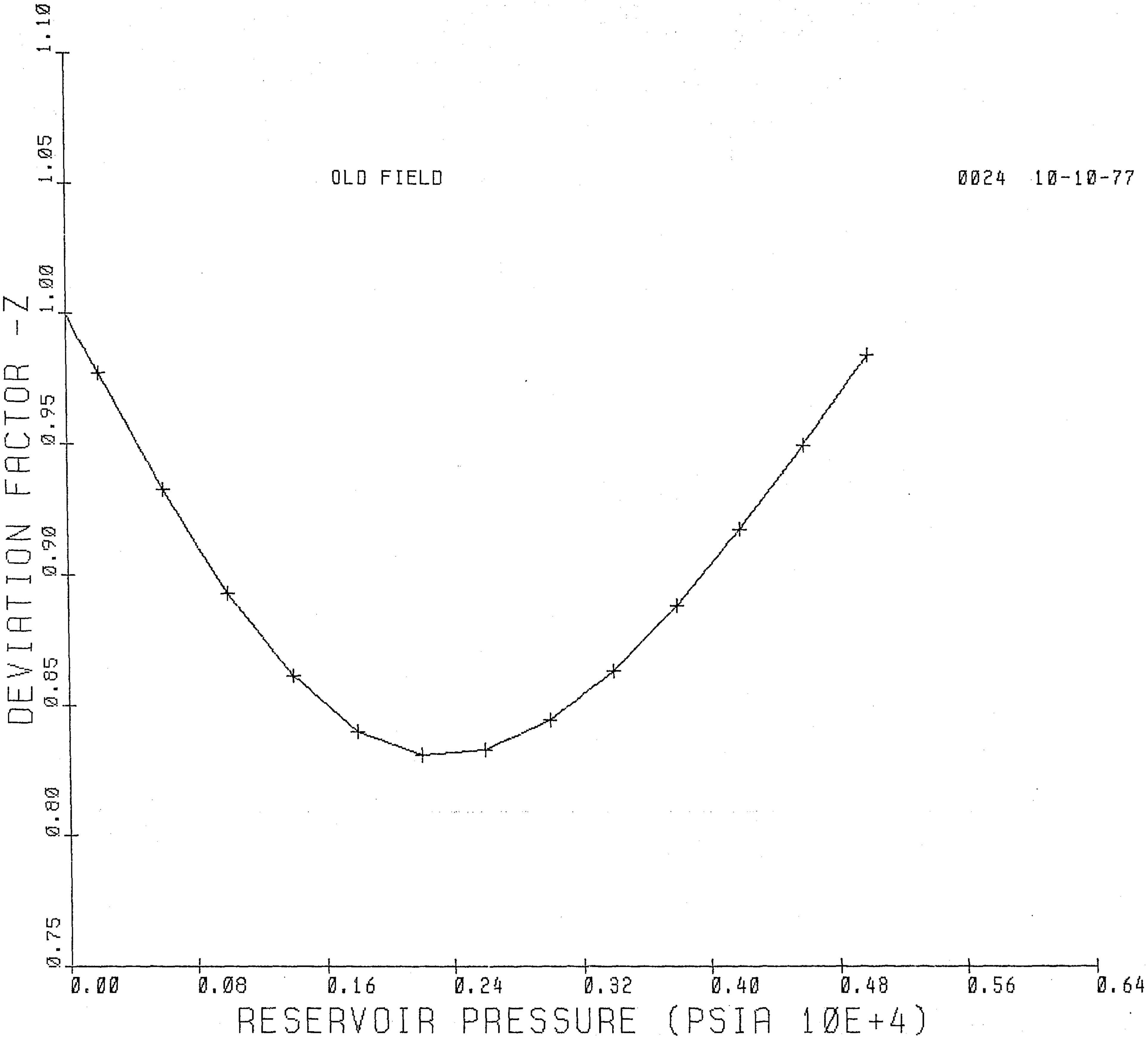
LPG = 28.89 BARRELS/MMSCF RAW GAS,(162.19 CUBIC METRES/MM CUBIC METRES)

CONDENSATE = 73.10 BARRELS/MMSCF RAW GAS,(410.44 CUBIC METRES/MM CUBIC METRES)

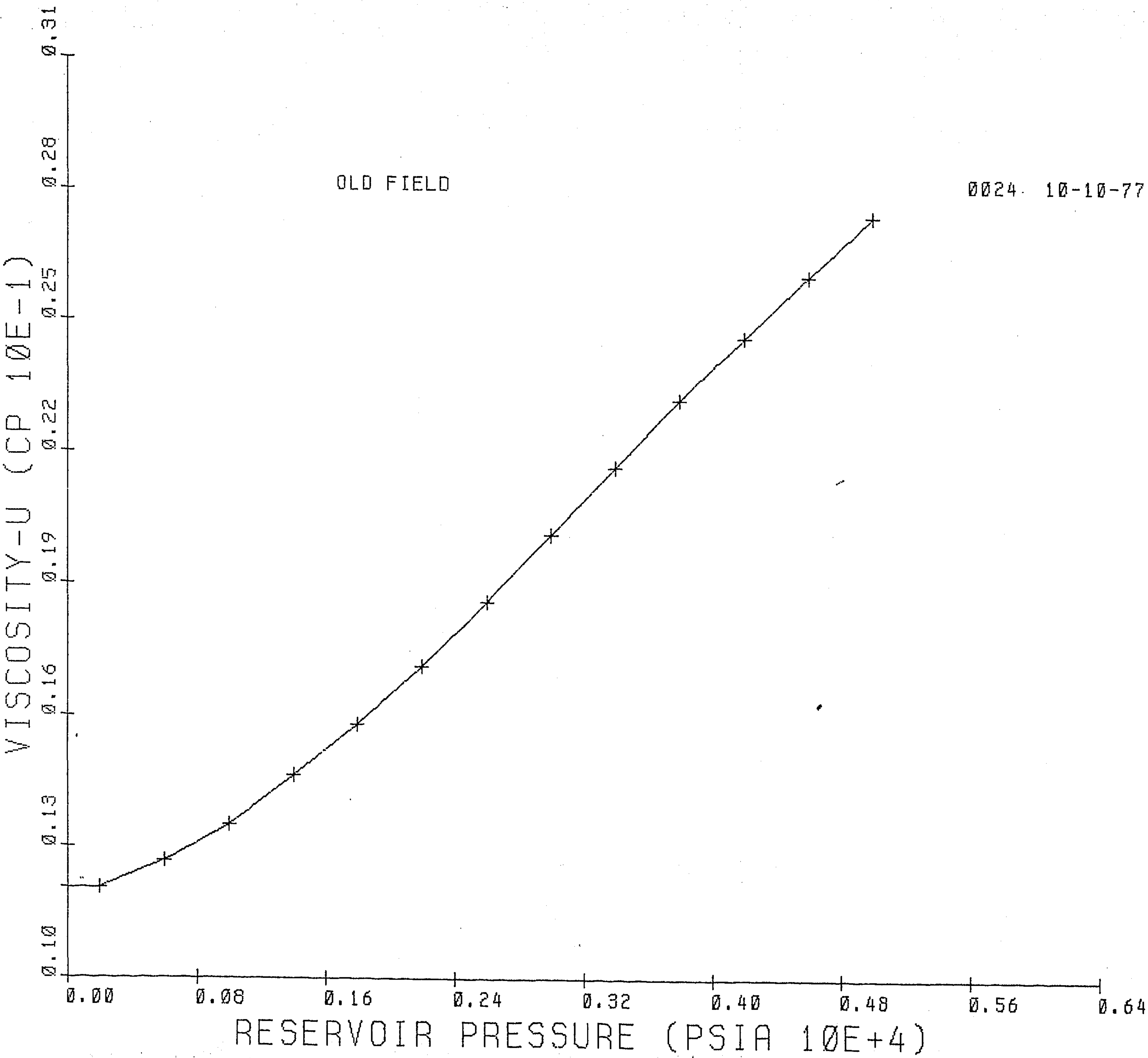
GAS/CONDENSATE (OR OIL) RATIO = 13679. CUBIC FEET / BARREL

RESERVOIR PRESSURE (PSIA)	RESERVOIR TEMPERATURE (F)	GAS DEVIATION FACTOR (Z)	VISCOSITY AT RESERVOIR CONDITIONS (CP)	COMPRESS-IBILITY (PSIA*-1)	GAS DENSITY (LB/CU.FT.) ((GM/CC))	GAS GRADIENT (PSI/FT)
5000.0	200.0	.984	.0274	.000120	16.806 (.269)	.1167
4600.0	200.0	.949	.0260	.000140	16.023 (.257)	.1113
4200.0	200.0	.917	.0246	.000165	15.143 (.243)	.1052
3800.0	200.0	.888	.0232	.000197	14.149 (.227)	.0983
3400.0	200.0	.863	.0216	.000239	13.025 (.209)	.0904
3000.0	200.0	.844	.0201	.000294	11.753 (.188)	.0816
2600.0	200.0	.833	.0186	.000369	10.329 (.165)	.0717
2200.0	200.0	.831	.0171	.000468	8.761 (.140)	.0608
1800.0	200.0	.840	.0158	.000603	7.088 (.114)	.0492
1400.0	200.0	.861	.0146	.000793	5.377 (.086)	.0373
1000.0	200.0	.893	.0135	.001101	3.704 (.059)	.0257
600.0	200.0	.932	.0127	.001780	2.129 (.034)	.0148
200.0	200.0	.977	.0120	.005118	.677 (.011)	.0047

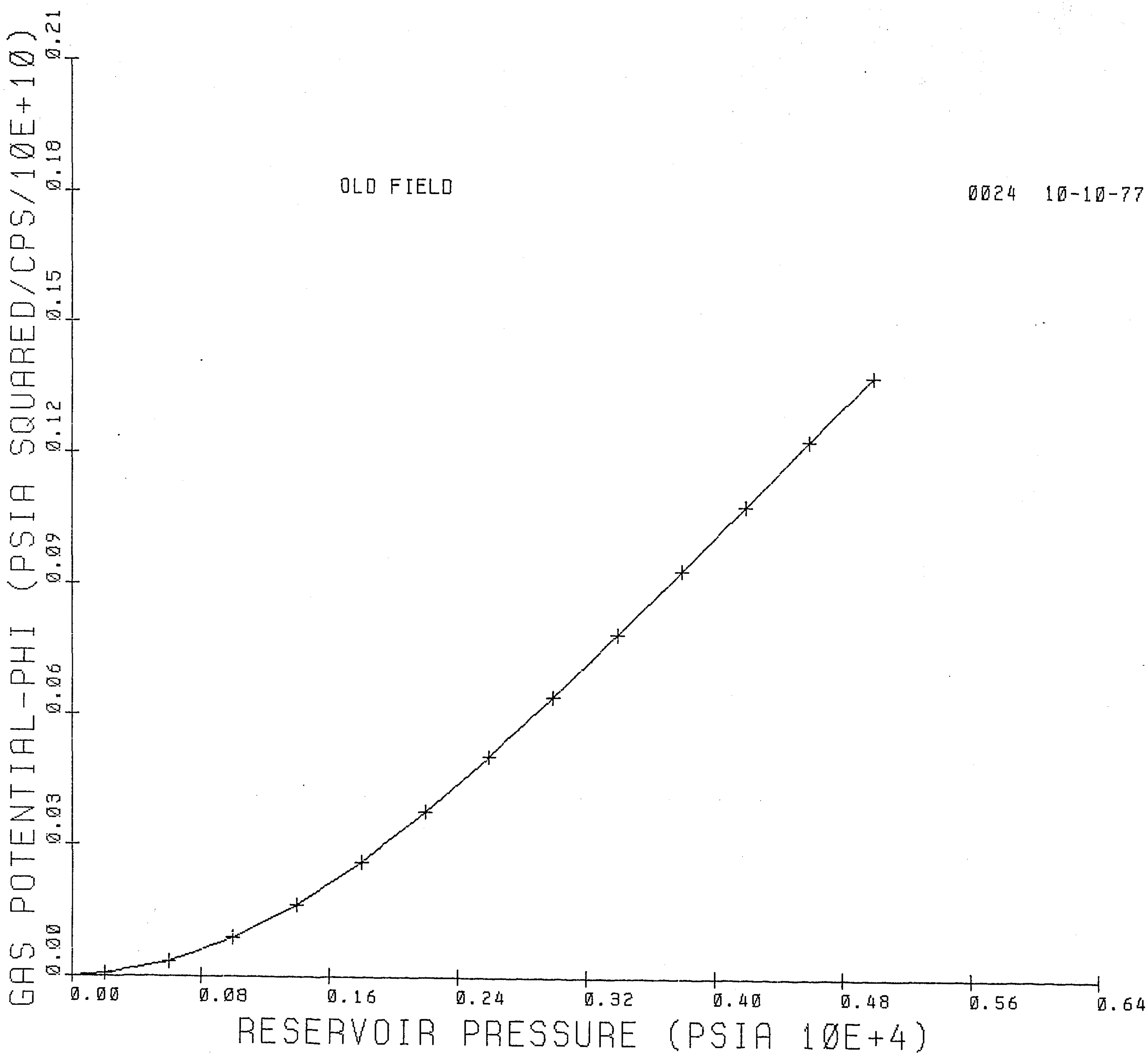
YR	RATE PER WELL RAW GAS MMCFD	ANNUAL PRODUCTION SALES GAS BCF	ANNUAL PRODUCTION LPG MBBL	ANNUAL PRODUCTION COND MBBL	CUMULATIVE PRODUCTION SALES GAS BCF	CUMULATIVE PRODUCTION LPG MMBBL	CUMULATIVE PRODUCTION COND MMBBL	FRAC PROD	PRESSURES (PSIA) TOP	PRESSURES (PSIA) BOT	PRESSURES (PSIA) RES
1	50.00	406.06	13122.90	29756.70	406.06	13.123	29.757	.0456	2409.7	3824.5	4676.5
2	50.00	406.06	13061.99	25902.83	812.12	26.185	55.660	.0913	2087.2	3472.7	4329.9
3	50.00	406.06	13047.96	23061.10	1218.19	39.233	78.721	.1369	1751.5	3127.8	3995.3
4	50.00	406.06	13047.96	20685.57	1624.25	52.281	99.406	.1825	1396.2	2801.2	3685.6
5	46.12	374.54	12035.02	17073.87	1998.79	64.316	116.480	.2246	1267.6	2569.0	3402.1
6	41.69	338.55	10872.76	14385.12	2337.34	75.189	130.865	.2626	1268.7	2429.7	3198.6
7	38.45	312.27	10009.11	13020.53	2649.61	85.198	143.886	.2977	1222.5	2289.1	3015.0
8	34.76	282.27	9032.77	11583.88	2931.88	94.230	155.470	.3294	1241.7	2198.3	2862.9
9	31.42	255.15	8153.12	10321.77	3187.03	102.384	165.791	.3581	1246.6	2110.6	2727.7
10	28.98	235.34	7510.24	9394.71	3422.37	109.894	175.186	.3845	1218.4	2017.1	2604.1
11	26.19	212.73	6781.18	8397.40	3635.10	116.675	183.584	.4084	1233.2	1963.2	2501.1
12	24.16	196.21	6248.40	7665.27	3831.32	122.923	191.249	.4305	1221.5	1902.4	2406.5
13	21.84	177.36	5642.89	6863.32	4008.68	128.566	198.112	.4504	1227.7	1858.2	2321.1
14	19.74	160.32	5099.57	6181.87	4169.00	133.666	204.294	.4684	1230.2	1818.3	2244.0
15	18.21	147.88	4703.68	5693.56	4316.88	138.370	209.988	.4850	1217.4	1773.7	2174.9
16	16.46	133.67	4251.75	5139.95	4450.55	142.621	215.128	.5001	1222.0	1748.2	2115.0
17	14.88	120.83	3843.25	4640.72	4571.37	146.465	219.768	.5136	1224.0	1724.9	2060.7
18	13.45	109.22	3473.99	4190.43	4680.59	149.939	223.959	.5259	1224.1	1703.7	2011.5
19	12.16	98.72	3140.21	3784.20	4779.31	153.079	227.743	.5370	1222.8	1684.4	1966.9
20	10.99	89.24	2838.50	3417.66	4868.55	155.917	231.161	.5470	1220.5	1666.9	1926.5
21	9.93	80.66	2565.78	3086.87	4949.21	158.483	234.247	.5561	1217.5	1650.9	1889.9
22	8.80	71.46	2272.88	2732.57	5020.67	160.756	236.980	.5641	1219.4	1641.8	1857.4
23	7.95	64.59	2054.50	2468.47	5085.26	162.810	239.448	.5714	1215.6	1628.9	1828.0
24	7.05	57.22	1819.97	2185.45	5142.47	164.630	241.634	.5778	1215.7	1621.5	1801.9

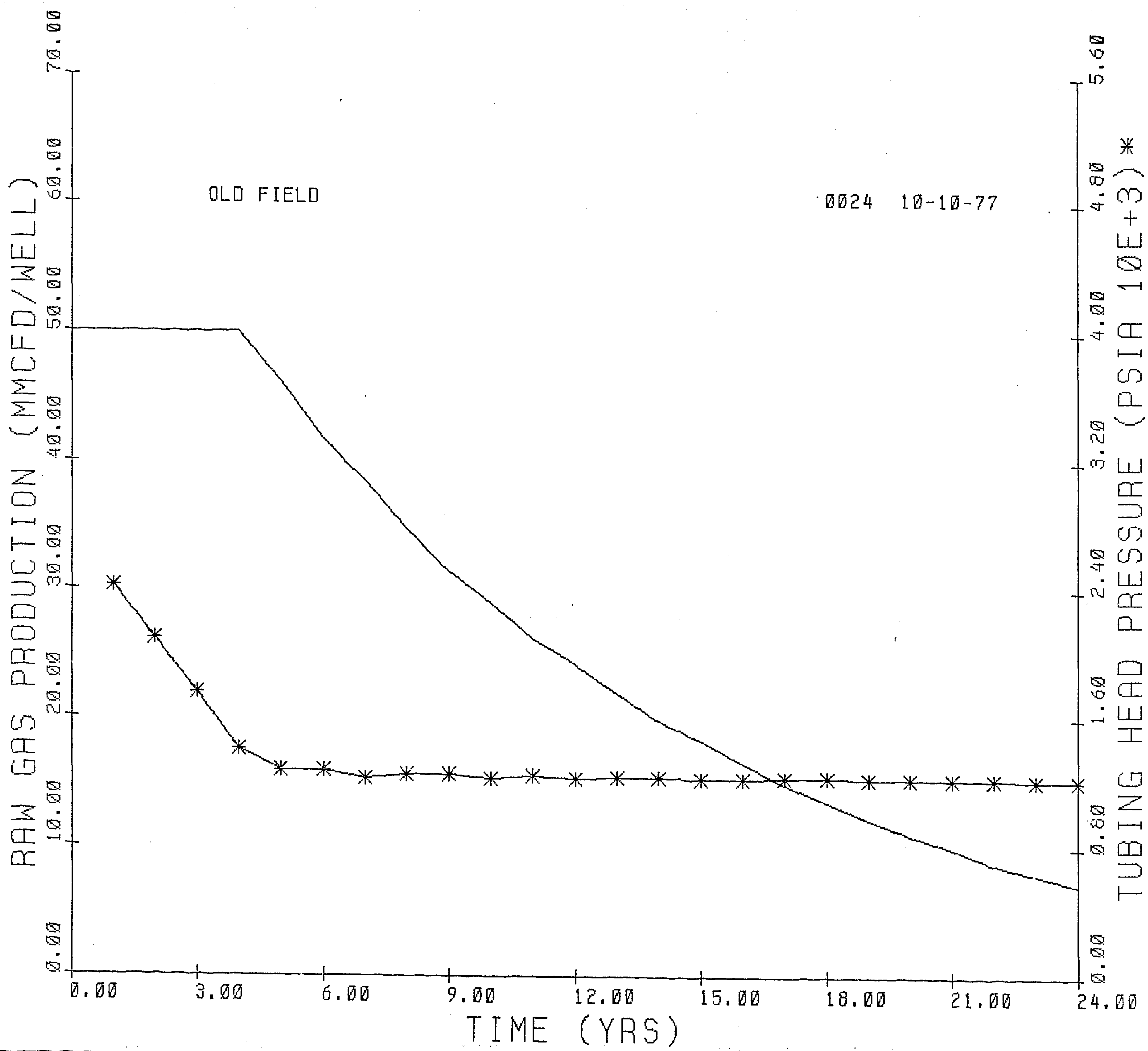


OLD FIELD
ØØ24 1Ø-1Ø-77
DEVIATION FACTOR -Z
1.1Ø
1.Ø5
1.ØØ
Ø.95
Ø.9Ø
Ø.85
Ø.8Ø
Ø.75
Ø.ØØ
Ø.Ø8
Ø.16
Ø.24
Ø.32
Ø.4Ø
Ø.48
Ø.56
Ø.64
RESERVOIR PRESSURE (PSIA 1ØE+4)



OLD FIELD
ØØ24 1Ø-1Ø-77
VISCOSITY-U (CP 1ØE-1)
Ø.1Ø
Ø.13
Ø.16
Ø.19
Ø.22
Ø.25
Ø.28
Ø.31
Ø.00
Ø.08
Ø.16
Ø.24
Ø.32
Ø.40
Ø.48
Ø.56
Ø.64
RESERVOIR PRESSURE (PSIA 1ØE+4)

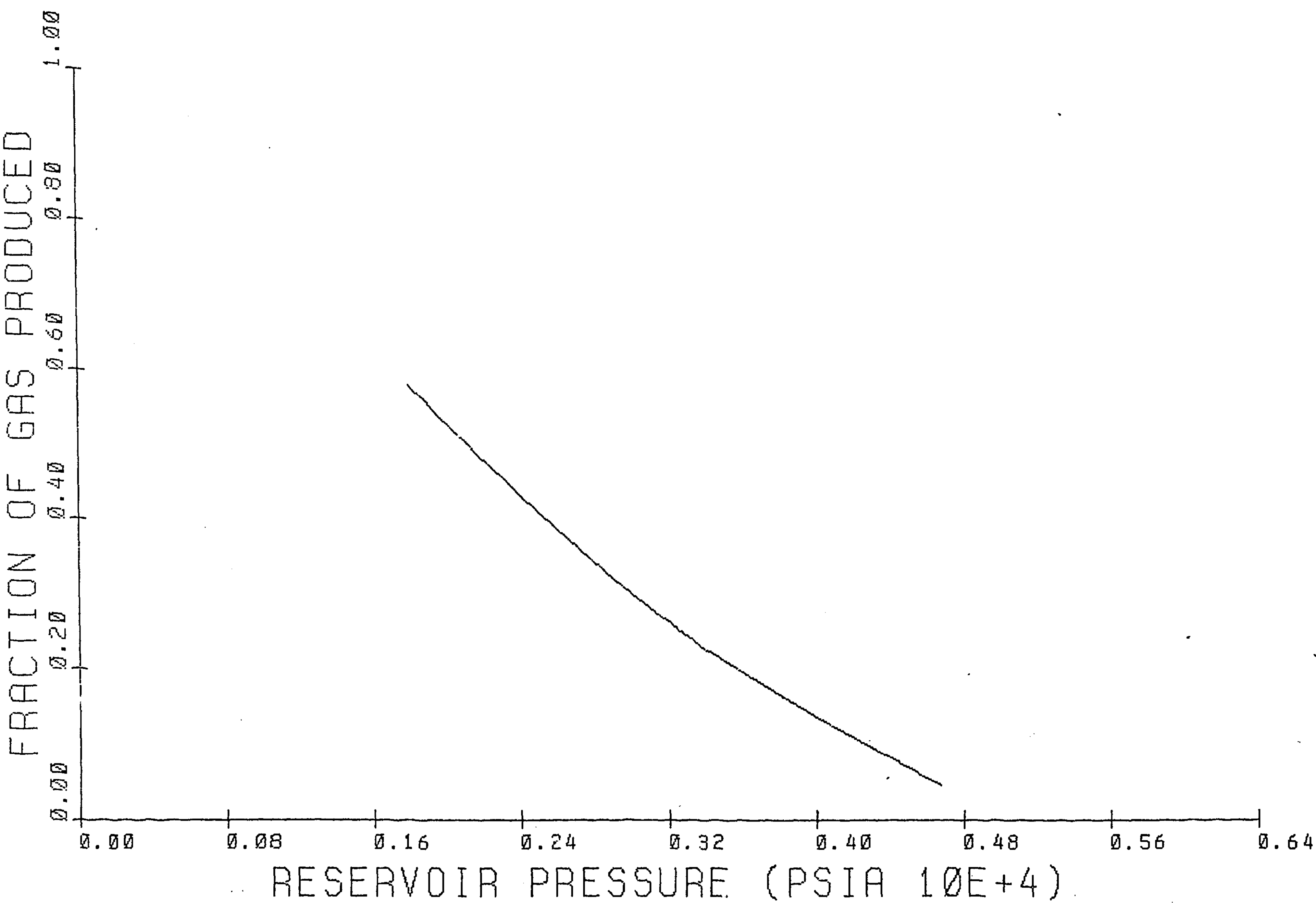

OLD FIELD
ØØ24 1Ø-1Ø-77
GAS POTENTIAL-PHI (PSIA SQUARED/CPS/1ØE+1Ø)
Ø.00
Ø.03
Ø.06
Ø.09
Ø.12
Ø.15
Ø.18
Ø.21
Ø.00
Ø.08
Ø.16
Ø.24
Ø.32
Ø.40
Ø.48
Ø.56
Ø.64
RESERVOIR PRESSURE (PSIA 1ØE+4)

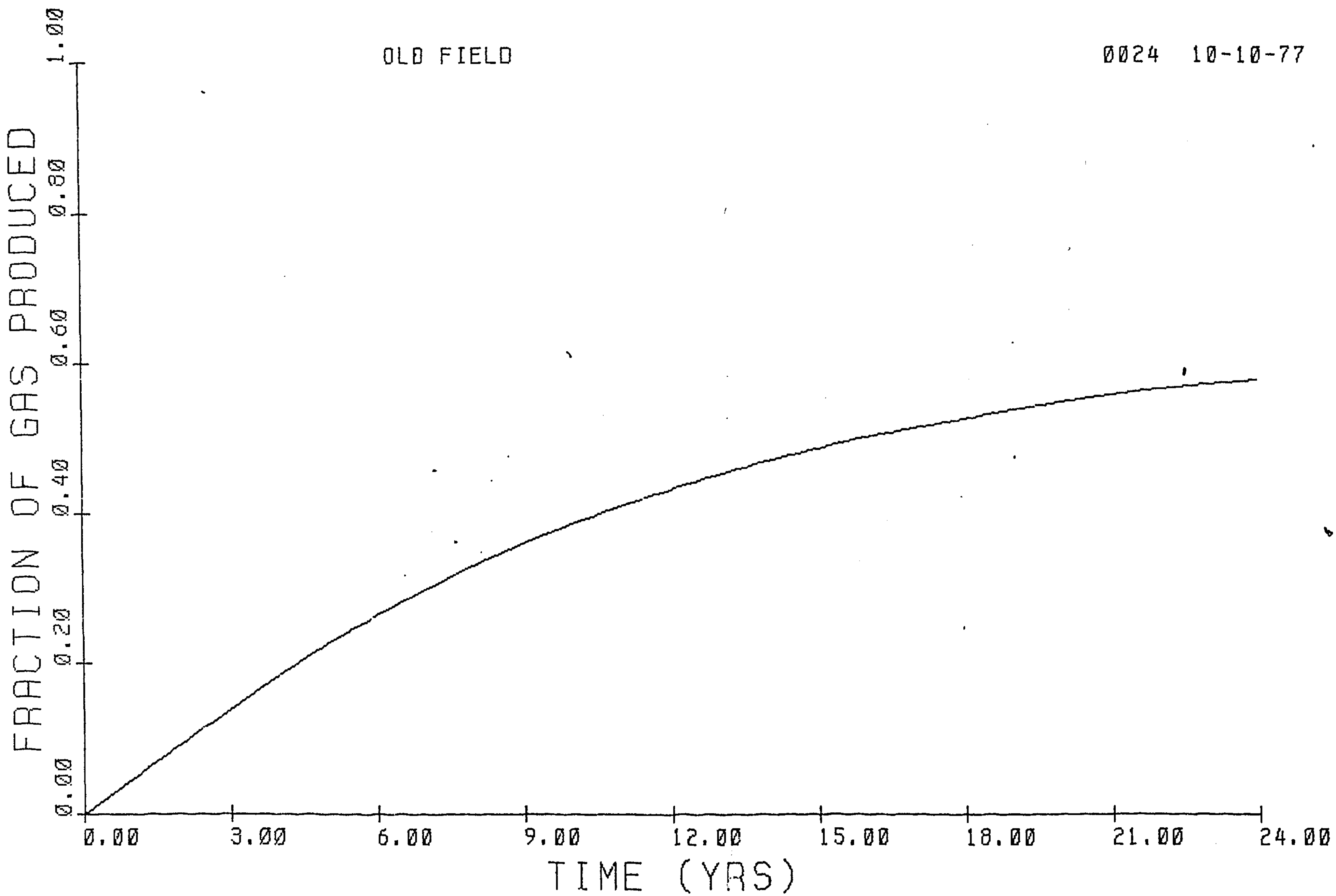


OLD FIELD
ØØ24 1Ø-1Ø-77
RAW GAS PRODUCTION (MMCFD/WELL)
TUBING HEAD PRESSURE (PSIA 1ØE+3)*
TIME (YRS)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
0.00
0.80
1.60
2.40
3.20
4.00
4.80
5.60
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00

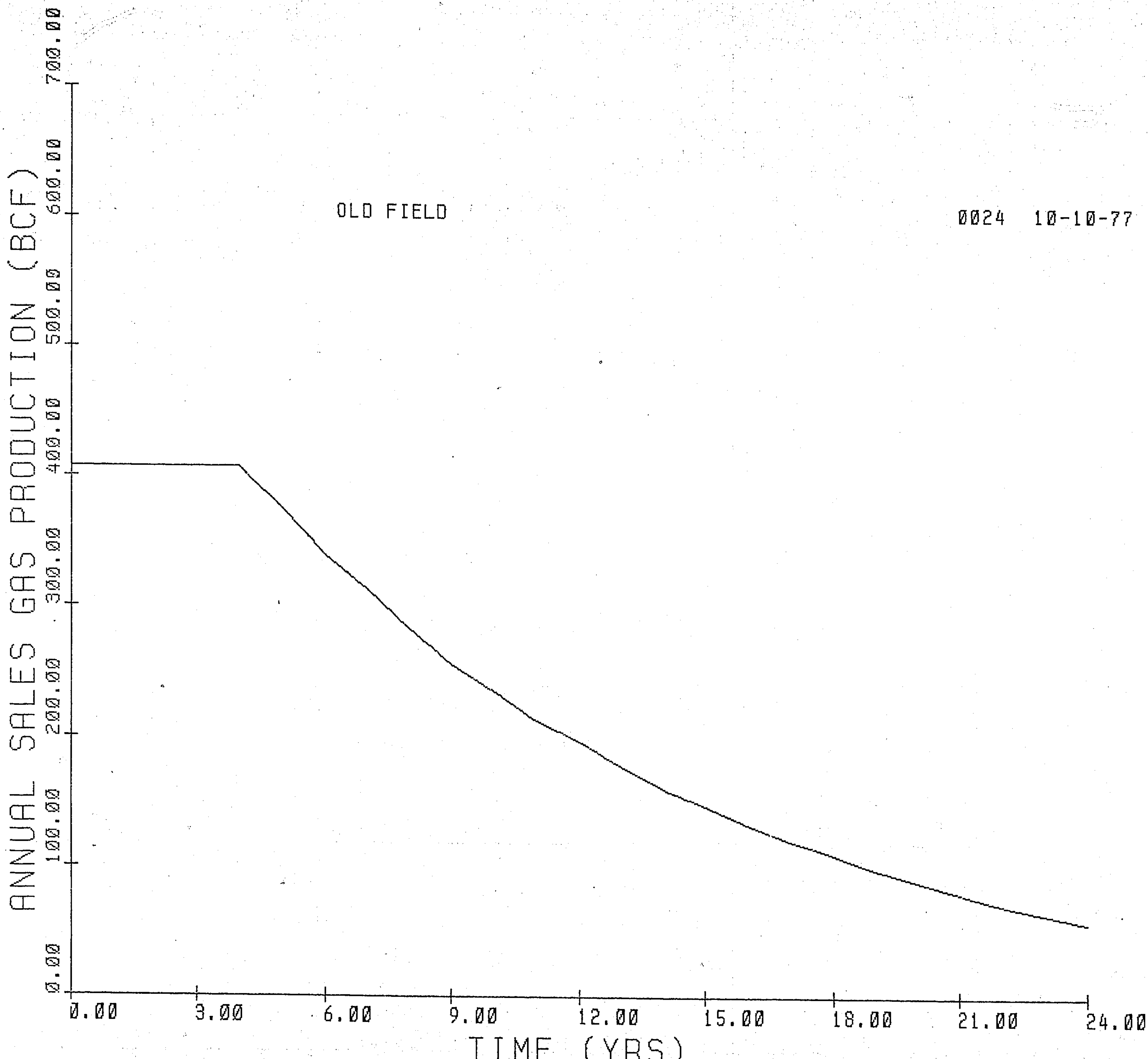
OLD FIELD

0024 10-10-77

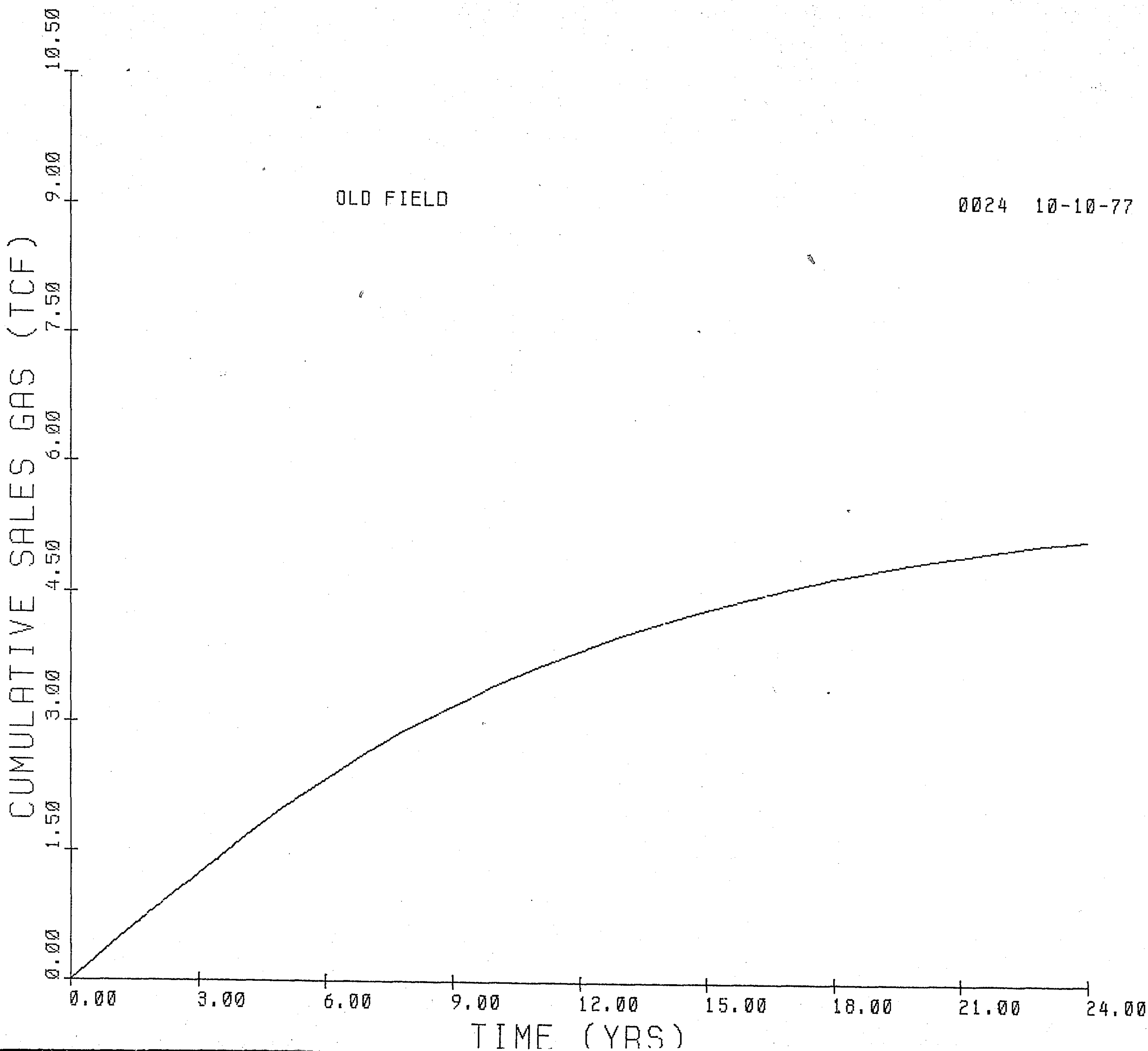


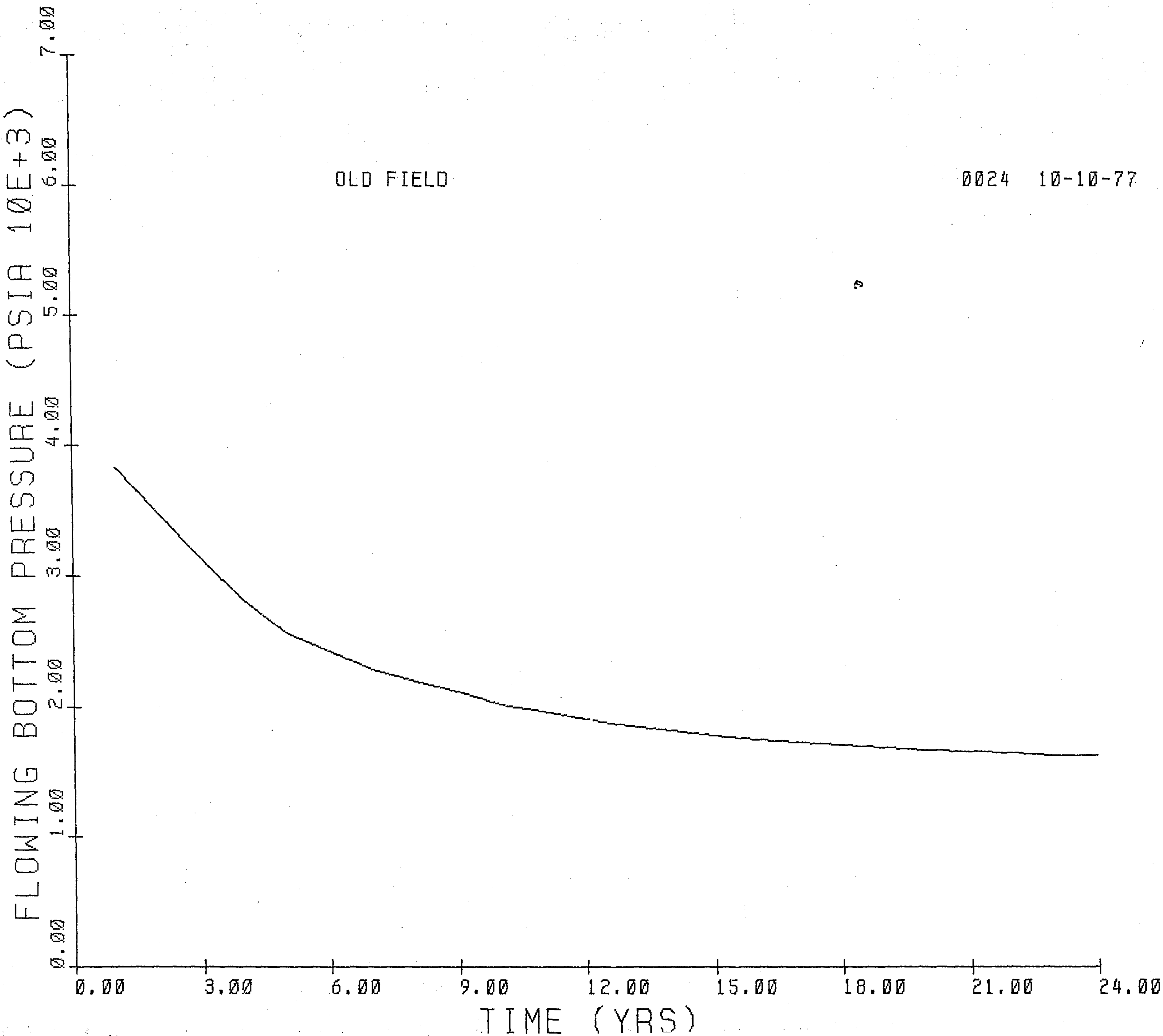


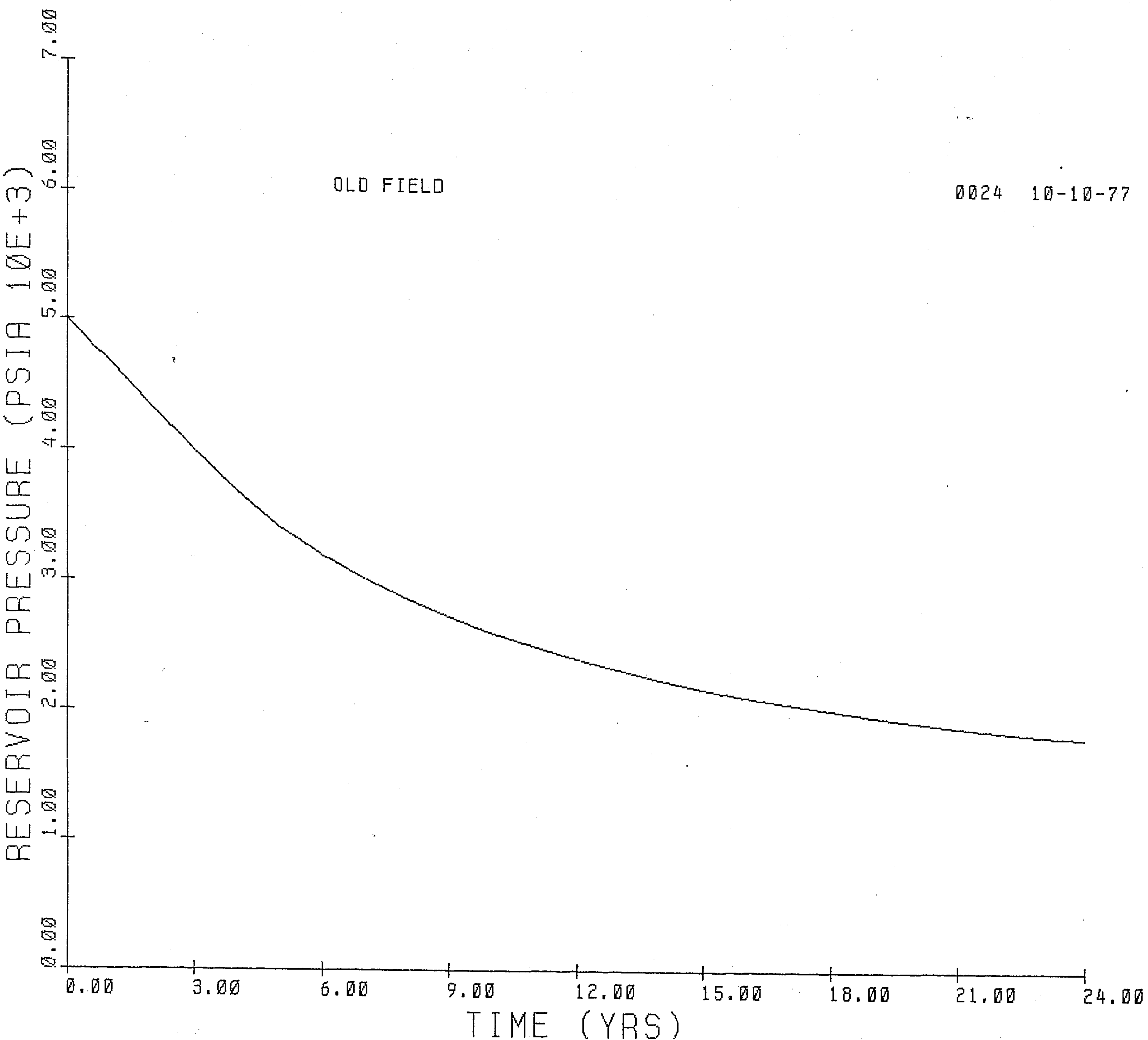
OLD FIELD
0024 10-10-77
FRACTION OF GAS PRODUCED
0.00
0.20
0.40
0.60
0.80
1.00
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00
TIME (YRS)

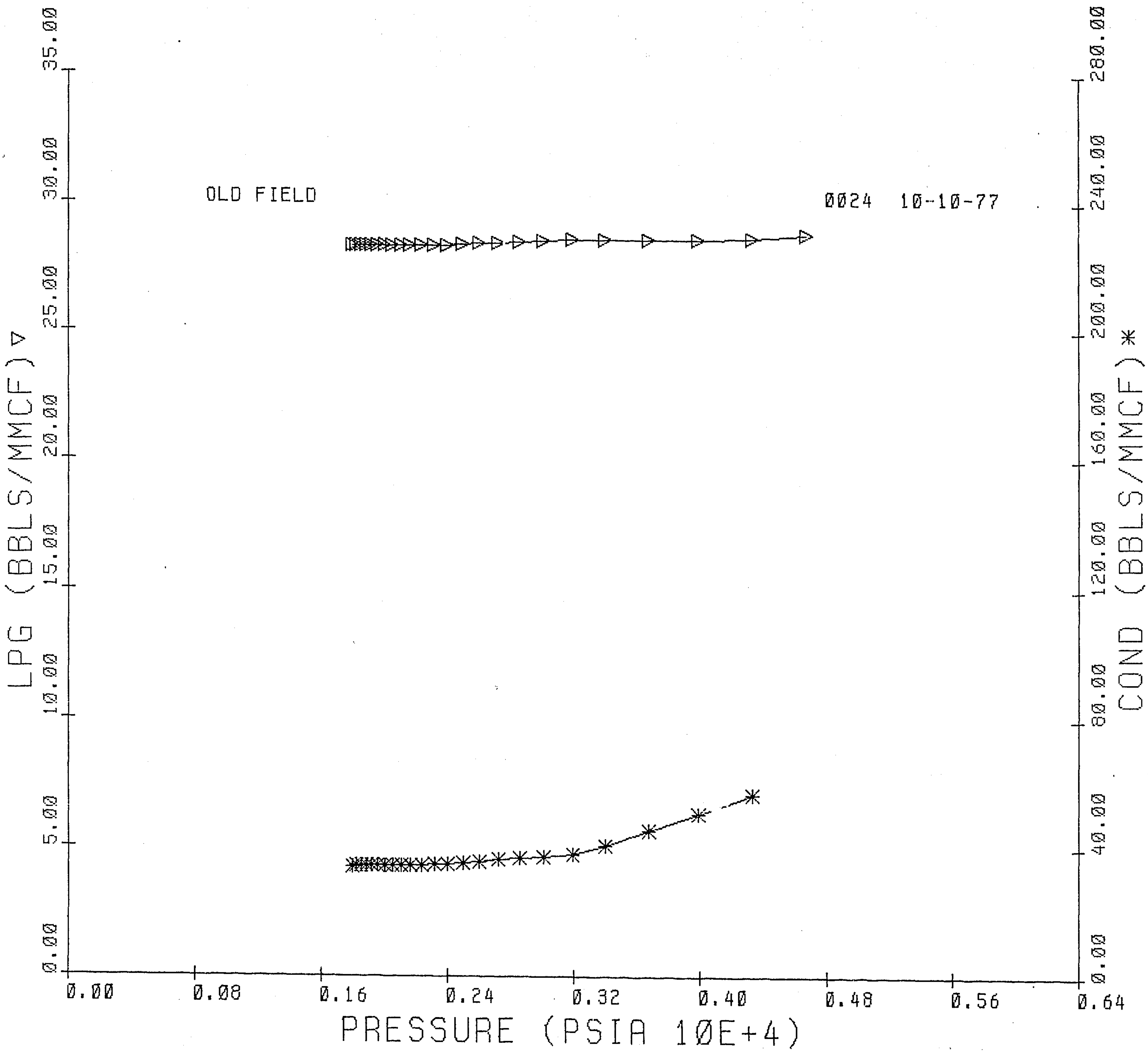


OLD FIELD
0024 10-10-77
ANNUAL SALES GAS PRODUCTION (BCF)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00
TIME (YRS)


OLD FIELD
0024 10-10-77
CUMULATIVE SALES GAS (TCF)
0.00
1.50
3.00
4.50
6.00
7.50
9.00
10.50
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00
TIME (YRS)


OLD FIELD
0024 10-10-77
FLOWING BOTTOM PRESSURE (PSIA 10E+3)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00
TIME (YRS)


OLD FIELD
0024 10-10-77
RESERVOIR PRESSURE (PSIA 10E+3)
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00
TIME (YRS)



OLD FIELD
0024 10-10-77
LPG (BBLS/MMCF) ▽
COND (BBLS/MMCF) *
PRESSURE (PSIA 10E+4)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
0.00
0.08
0.16
0.24
0.32
0.40
0.48
0.56
0.64

APPENDIX 3

SOURCE CODE LISTING

```
FTN4,B
      PROGRAM GAS1(3)
      DIMENSION NAME(3),IB(5)
      COMMON IDUM(539)
      DATA NAME /2HGA,2HS2,2H  /
      CALL EXEC (8,NAME,IB)
      END
      PROGRAM GAS2(5)
C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
C     PREPARED BY K.L.STILLWELL & L.E.KURYLOWICZ 27/9/76
C    ***************************************************************
C    *  PROGRAM TO CALCULATE PSEUDO-CRITICAL TEMPERATURE &PRESSURE,*
C    *  MOLECULAR WEIGHT,SPECIFIC GRAVITY,CALORIFIC VALUE OF SALES *
C    *  GAS FRACTION,LPG & CONDENSATE FRACTIONS, GAS DEVIATION (OR *
C    *  COMPRESSIBILITY) FACTOR,COMPRESSIBILITY,VISCOSITY,DENSITY, *
C    *  AND GRADIENT OF NATURAL GASES-                             *
C    *  CUMULATIVE RECOVERY OF SALES GAS,LPG,CONDENSATE,RECOVERY   *
C    *  FACTOR,AND THE MONITORING OF TUBING HEAD,FLOWING BOTTOM-   *
C    *  HOLE ,AND RESERVOIR PRESSURES DURING DEPLETION             *
C    ***************************************************************
C     LIST OF NAMES AND VARIABLES
C     MW=MOLECULAR WEIGHT
C     PR=PSEUDO-REDUCED PRESSURE
C     TR=PSEUDO-REDUCED TEMPERATURE
C     P=PRESSURE INITIAL RESERVOIR  (PSIA)
C     T=TEMPERATURE  INITIAL IN RESERVOIR (DEGREES FAHRENHEIT)
C     MF PREFIX INDICATES MOL FRACTION
C     PC PREFIX INDICATES CRITICAL PRESSURE
C     TC PREFIX INDICATES CRITICAL TEMPERATURE
C     C1=METHANE
C     C2=ETHANE
C     C3=PROPANE
C     C4I=ISO-BUTANE
C     C4N=N-BUTANE
C     C5I=ISO-PENTANE
C     C5N=N-PENTANE
C     C6=HEXANES
C     C7P=HEPTANES PLUS
C     H2S=HYDROGEN SULPHIDE
C     CO2=CARBON DIOXIDE
C     N2=NITROGEN
C     Z=DEVIATION FACTOR(OR COMPRESSIBILITY)
C     SG=SPECIFIC GRAVITY (AIR=1)
```

```
C       MWAVG=AVERAGE MOLECULAR WEIGHT OF GAS
C       TOT=TØTAL MOL FRACTION
C       SALG=SALES GAS(METHANE+ETHANE+UP TO 3%CARBON DIOXIDE)
C       CALG=CALORIFIC VALUE OF GAS ON DRY-BASIS
C       LPG=LIQUIFIED PETROLEUM GAS (PROPANE+BUTANES)
C       COND=CONDENSATE   (PENTANES+HEXANES+HEPTANES PLUS )
C       GOR=GAS / CONDENSATE (OR OIL)RATIO
C       Z=GAS DEVIATION FACTOR
C       VISG=VISCOSITY (CENTIPOISE)
C       POSTSCRIPT M=METRIC
C       LUN= DEBUG INTEGER (EQUAL TO 6 IF YES)
C       ICODE=GAS FLOW CALCULATION BY-PASS (EQUAL TO 1 IF YES)
C       IPL  PLOT SWITCH (1-YES,0-NO)
C       KPMAX=0 IF NO PVT, =1 WHEN LPG & COND CALCULATED ALLOWING
C       FOR RETROGRADE CONDENSATION
C       VOL         VOLUME OF GAS INITIALLY IN PLACE (MMSCF)
C       POR         POROSITY (FRACTION)
C       SATW        SATURATION, WATER (FRACTION)
C       AVETH       AVERAGE THICKNESS OF RESERVOIR (FEET)
C       NYRMAX      YEARS PREDICTION REQUIRED
C       NW          NO. OF WELLS
C       NP          NO. OF PRESSURE POINTS TO BE TABULATED
C       PTAB (M)    TABULATION OF PRESSURES FOR DEVIATION FACTOR AND VISCOSITY (PSIA)
C       ZTAB (M)    TABULATION OF DEVIATION FACTORS FOR PTAB (M)
C       UTAB (M)    TABULATION OF VISCOSITY VALUES FOR PTAB (M) (CPS.)
C       RW          WELL RADIUS (FT.)
C       KH          PERMEABILITY-THICKNESS (MDS.-FT.)
C       S           SKIN FACTOR
C       Q           GAS WELL PRODUCTION RATE  (MMSCF/D)  GROSS GAS
C       QMIN        MINIMUM PRODUCTION RATE (MMSCF/D/WELL)
C       THPMIN      MINIMUM TUBING PRESSURE
C       QOVER       PEAK Q / Q (RATIO)
C       GASGR       GAS GRAVITY (AIR =1.)
C       TBGEL       TUBING ELEVATION (TVD)
C       TBGDIA      TUBING DIAMETER (INCH)
C       FR          FRICTION FACTOR
C       FAC         FACTOR ACTUAL LENGTH / TVD
C       TEMTOP      TEMPERATURE AT SURFACE IN TUBING (DEGREES FAHRENHEIT)
C       Q2 (N)      DAILY GAS PRODUCTION PER WELL GROSS GAS
C       GP (N)      ANNUAL GAS PRODUCTION (FIELD)  NET SALES GAS
C       GPLPG (N)ANNUAL LPG PRODUCTION (FIELD)
C       GPCON (N)ANNUAL CONDENSATE PRODUCTION(FIELD)
C       QOVOL (N)FRACTION OF GAS INITIALLY IN PLACE PRODUCED
C       SUMGP (N) CUMULATIVE GP
```

```
C      SUMLPG(N) CUMULATIVE LPG
C      SUMCON(N) CUMULATIVE CONDENSATE
       REAL MWC1,MWC2,MWC3,MWC4I,MWC4N,MWC5I,MWC5N,MWC6,MWC7P,MWH2S,
      1MWN2,MFC1,MFC2,MFC3,MFC4I,MFC4N,MFC5I,MFC5N,MFC6,MFC7P,MFH2S,
      2MFN2,MWAVG,MWCO2,MFCO2,LPG,LPGM,KH,MFC7R
       INTEGER TITLE
       DIMENSION NAME(5),DELPOT(30)
       COMMON TITLE(26),LUN,ICODE,KPMAX,TR,PR,CTAV,CPAV,SG,PP(30),
      A ZZ(30),VISGG(30),MFH2S,MFCO2,MFN2,I,IJ,POT(30),PTAB(30),
      B ZTAB(30),UTAB(30),SALG,BLPG(10),BC5(10),PA(10),LPG,COND,P,T,
      C KP1MAX,IPL
       DATA NAME /2HGA,2HS3,2H  /
       READ(5,20)TITLE,LUN,ICODE,KPMAX,IPL
   20  FORMAT(20A2,/,6A2,4I1)
       READ (5,*) MFC1,MFC2,MFC3,MFC4I,MFC4N,MFC5I,MFC5N,MFC6,MFC7P,
      2MFH2S,MFCO2,MFN2
       READ (5,*)P,T
       IF(P.LE.500.0.OR.P.GE.10000.0) STOP 1
       IF(T.LE.60.0.OR.T.GE.400.0) STOP 2
       IF(ICODE.EQ.1) GO TO 44
       IF(KPMAX.EQ.0) GO TO 44
       CALL GPM
C      THIS NEXT SECTION DEFINES THE MOLECULAR WEIGHT CRITICAL TEMPERATURES
C      AND PRESSURES OF GAS COMPONENTS
   44  MWC1=16.042
       MWC2=30.068
       MWC3=44.094
       MWC4I=58.12
       MWC4N=58.12
       MWC5I=72.146
       MWC5N=72.146
       MWC6=86.172
       MWC7P=114.224
       MWH2S=34.076
       MWCO2=44.01
       MWN2=28.016
       PCC1=673.1
       PCC2=708.3
       PCC3=617.4
       PCC4I=529.1
       PCC4N=550.7
       PCC5I=483.0
       PCC5N=489.5
       PCC6=439.7
```

```
      PCC7P=362.1
      PCH2S=1306.0
      PCN2=492.0
      PCCO2=1073.0
      TCC1=343.2
      TCC2=549.8
      TCC3=665.9
      TCC4I=734.6
      TCC4N=765.3
      TCC5I=829.7
      TCC5N=845.6
      TCC6=914.2
      TCC7P=1024.9
      TCH2S=672.4
      TCN2=226.9
      TCCO2=547.7
      IF(LUN.NE.6) LUN=3
      TOT=MFC1+MFC2+MFC3+MFC4I+MFC4N+MFC5I+MFC5N+MFC6+MFC7P+MFH2S+MFCO2+
     1MFN2
      IF(TOT.LE.0.9.OR.TOT.GE.1.2) STOP 3
      MWAVG=MFC1*MWC1+MFC2*MWC2+MFC3*MWC3+MFC4I*MWC4I+MFC4N*MWC4N+
     2MFC5I*MWC5I+MFC5N*MWC5N+MFC6*MWC6+MFC7P*MWC7P+MFN2*MWN2+MFCO2
     3*MWCO2+MFH2S*MWH2S
C     THIS NEXT SECTION CALCULATES PSEUDO-REDUCED PRESSURE
C     AND TEMPERATURE
C     CPAV=AVERAGE CRITICAL PRESSURE
      CPAV=MFC1*PCC1+MFC2*PCC2+MFC3*PCC3+MFC4I*PCC4I+MFC4N*PCC4N+MFC5I*P
     1CC5I+MFC5N*PCC5N+MFC6*PCC6+MFC7P*PCC7P+MFN2*PCN2+MFCO2*PCCO2+MFH2S
     2*PCH2S
C     CTAV=AVERAGE CRITICAL TEMPERATURE
      CTAV=MFC1*TCC1+MFC2*TCC2+MFC3*TCC3+MFC4I*TCC4I+MFC4N*TCC4N+MFC5I*T
     2CC5I+MFC5N*TCC5N+MFC6*TCC6+MFC7P*TCC7P+MFN2*TCN2+MFCO2*TCCO2+MFH2S
     3*TCH2S
      WRITE (6,81)(TITLE(J),J=1,26)
   81 FORMAT (1H1,5/,40X,20A2,22X,2A2,5X,4A2,1(/))
      WRITE (6,21)
   21 FORMAT(113X,"PAGE 2",/,
     *       6X,"COMPONENTS",16X,"MOLECULAR",16X,"CRITICAL",16X,"CRITIC
     1AL",19X,"MOL",/,33X,"WEIGHT",18X,"PRESSURE",14X,"TEMPERATURE",16X
     2,"FRACTION",/,58X,"(PSIA)",19X,"(R)")
      WRITE (6,22) MWC1,PCC1,TCC1,MFC1
   22 FORMAT (6X," METHANE",20X,F6.3,18X,F5.1,18X,F5.1,20X,F6.6,/)
      WRITE (6,23) MWC2,PCC2,TCC2,MFC2
   23 FORMAT (6X," ETHANE",21X,F6.3,18X,F5.1,18X,F5.1,20X,F6.6,/)
```

```
      WRITE (6,24) MWC3,PCC3,TCC3,MFC3
24    FORMAT (6X," PROPANE",20X,F6.3,18X,F5.1,18X,F5.1,20X,F6.6,/)
      WRITE (6,25) MWC4I,PCC4I,TCC4I,MFC4I
25    FORMAT (6X," ISO-BUTANE",17X,F6.3,18X,F5.1,18X,F5.1,20X,F6.6,/)
      WRITE (6,26) MWC4N,PCC4N,TCC4N,MFC4N
26    FORMAT (6X," N-BUTANE",19X,F6.3,18X,F5.1,18X,F5.1,20X,F6.6,/)
      WRITE (6,27) MWC5I,PCC5I,TCC5I,MFC5I
27    FORMAT (6X," ISO-PENTANE",16X,F6.3,18X,F5.1,18X,F5.1,20X,F6.6/)
      WRITE (6,28) MWC5N,PCC5N,TCC5N,MFC5N
28    FORMAT (6X," N-PENTANE",18X,F6.3,18X,F5.1,18X,F5.1,20X,F6.6,/)
      WRITE (6,29) MWC6,PCC6,TCC6,MFC6
29    FORMAT (6X," HEXANES",20X,F6.3,18X,F5.1,18X,F5.1,20X,F6.6/)
      WRITE (6,30) MWC7P,PCC7P,TCC7P,MFC7P
30    FORMAT (6X," HEPTANES PLUS" 14X,F6.3,18X,F5.1,17X,F6.1,20X,F6.6,/)
      WRITE (6,31) MWH2S,PCH2S,TCH2S,MFH2S
31    FORMAT (6X," HYDROGEN SULPHIDE",10X,F6.3,17X,F6.1,18X,F5.1,20X,F6.
     16,/)
      WRITE (6,32) MWCO2,PCCO2,TCCO2,MFCO2
32    FORMAT (6X," CARBON DIOXIDE",13X,F6.3,17X,F6.1,18X,F5.1,20X,F6.6,/
     1)
      WRITE (6,33) MWN2,PCN2,TCN2,MFN2,CPAV,CTAV,TOT
33    FORMAT (6X," NITROGEN",19X,F6.3,18X,F5.1,18X,F5.1,20X,F6.6,//46X
     1," AVERAGE",4X,F6.3,6X," AVERAGE",3X,F6.3,10X," TOTAL",2X,F7.7,
     2//)
      SG=MWAVG/28.966
      WRITE (6,4) MWAVG,SG
4     FORMAT (6X," AVERAGE MOLECULAR WEIGHT OF GAS =",4X,F5.3,20X,"GAS G
     1RAVITY =",2X,F4.4,/)
C     THIS NEXT SECTION CALCULATES SALES GAS,CALORIFIC VALUE
C     LPG,&CONDENSATE
      IF (MFCO2.GT.0.03) GO TO 777
      SALG=MFC1+MFC2+MFCO2
      X=1.0000/(MFC1+MFC2+MFCO2)
      GO TO 888
777   SALG=MFC1+MFC2+0.03
      X=1.0000/(MFC1+MFC2+0.03)
888   WRITE (6,6) SALG
6     FORMAT (6X," SALES GAS",23X,"=",5X,F6.4,2X,"MMSCF/MMSCF RAW GAS",
     A/)
      MFC1=X*MFC1
      MFC2=X*MFC2
      CALG=MFC1*1012.0+MFC2*1783
      CALGM=CALG*37259.08778
      WRITE (6,7) CALG,CALGM
```

```
7     FORMAT (6X," DRY-BASIS HEATING VALUE",9X,"="1X,F6.0,6X,"BTU/CUB",
     1"IC FOOT VAPOR ",
     2"AT 14.696 PSIA,",/,45X,"(",E10.5,2X,"JOULE/CUBIC METRE)",/)
      LPG=MFC3*1.E6/1502.76+MFC4I*1.E6/1247.4+MFC4N*1.E6/1292.34
      LPGM=LPG*5.614589899
      WRITE (6,8) LPG,LPGM
8     FORMAT (6X," LPG",29X,"=",3X,F6.2,4X,"BARRELS/MMSCF RAW GAS,(",
     1F7.2,2X,"CUBIC METRES/MM CUBIC METRES)",/)
      COND=MFC5I*1.E6/1150.716+MFC5N*1.E6/1162.56+MFC6*1.E6/1024.0+MFC7P
     1*1.E6/822.234
      CONDM=COND*5.614589899
      GOR=1000000.0/COND
      WRITE (6,9)COND,CONDM,GOR
9     FORMAT (6X," CONDENSATE",21X," =",3X,F6.2,4X,"BARRELS/MMSCF RAW "
     1"GAS,(",F7.2,2X,"CUBIC METRES/MM CUBIC METRES)",2(/),7X,
     2"GAS/CONDENSATE (OR OIL) RATIO",3X,"=",2X,F7.0,4X,"CUBIC FEET / BA
     3RREL",/)
      IF(KPMAX.NE.0) GO TO 900
      CALL DUM
900   WRITE(6,81)(TITLE(J),J=1,26)
      WRITE (6,40)
 40   FORMAT (113X,"PAGE 3",/,
     * 7X,"RESERVOIR",7X,"RESERVOIR",10X,"GAS",10X,"VISCOSITY",8X,
     A"COMPRESS-",9X,"GAS",12X,"GAS",/,7X,"PRESSURE",8X,"TEMPERATURE"
     B,6X,"DEVIATION",6X,"AT RESERVOIR",5X,"IBILITY",9X,"DENSITY",8X,
     C"GRADIENT",/,41X,"FACTOR",8X,"CONDITIONS",20X,"(LB/CU.FT.)",/,
     D7X,"(PSIA)",12X,"(F)",14X,"(Z)",13X,"(CP)",10X,"(PSIA*-1)",6X,
     E"((GM/CC))",7X,"(PSI/FT)",/)
      IJ=1
      DO 50 I=1,30
      CALL ZSTAR (CMPG)
      CALL VISCY
      DENG=(MWAVG*PP(I)*520.0)/(379.0*14.73*(T+460.0)*ZZ(I))
      DENGM=DENG*0.0160185
      GRDG=DENG/144.0
      WRITE (6,41) PP(I),T,ZZ(I),VISGG(I),CMPG,DENG,DENGM,GRDG
 41   FORMAT(8X,F6.1,10X,F5.1,11X,F5.3,12X,F5.4,10X,F7.6,7X,F6.3,1X,"(",
     AF4.3,")",5X,F5.4/)
      IP=P/100
      P=IP*100.0-400.0
      IF(P.LE.1.0) GO TO 60
 50   CONTINUE
 60   PP(I+1)=0.0
      ZZ(I+1)=1.0
```

```
      VISGG(I+1)=VISGG(I)
      I=I+1
      NP=I
      CALL  INVER (PTAB,PP, NP,LUN)
      CALL  INVER (ZTAB,ZZ,NP,LUN)
      CALL  INVER (UTAB,VISGG,NP,LUN)
C     USING AL-HUSSAINY-RAMEY METHOD,"THE FLOW OF REAL GASES THROUGH
C     POROUS MEDIA.",JPT,MAY66,PP 624-642
C     CALCULATION OF GAS POTENTIAL FOLLOWS
      DO 100 M =1, NP
      DELPOT(M)= 2.0 * PTAB (M) /ZTAB (M) /UTAB (M)
  100 CONTINUE
  101 CALL QINTE (POT, DELPOT, PTAB, NP,LUN)
      WRITE(LUN,301)(( PTAB(M),DELPOT(M),POT(M)),M=1,NP)
 301  FORMAT (2X,F8.1,2X,"DELPOT=",2X,E13.6,10X "POT = ",2X, E13.6)
      IF (IPL.NE.1) GO TO 999
      CALL ZMPL (NP,TITLE,PTAB,ZTAB,UTAB,POT)
 999  CALL EXEC (8,NAME,TITLE)
      CALL GAS1
      END
      SUBROUTINE GPM
      INTEGER TITLE
      REAL MFH2S,MFCO2,MFN2,LPG
      COMMON TITLE(26),LUN,ICODE,KPMAX,TR,PR,CTAV,CPAV,SG,PP(30),
     A ZZ(30),VISGG(30),MFH2S,MFCO2,MFN2,I,IJ,POT(30),PTAB(30),
     B ZTAB(30),UTAB(30),SALG,BLPG(10),BC5(10),PA(10),LPG,COND,P,T,
     C KP1MAX,IPL
      DIMENSION PAI(10),GAS(10),C3P(10),C5P(10),BLPGI(10),BC5I(10)
      READ (5,*)(PAI(K),K=1,KPMAX)
      READ(5,*) (C3P(K),K=1,KPMAX)
      READ (5,*)(C5P(K),K=1,KPMAX)
      KPMAX=KPMAX+1
      PAI(KPMAX)=0.0
      GAS(KPMAX)=0.996*GAS(KPMAX-1)
      C3P(KPMAX)=C3P(KPMAX-1)
      C5P(KPMAX)=C5P(KPMAX-1)
      BLPGI(1)=C3P(1)
      BC5I(1)=C5P(1)
      DO 25 K=1,KPMAX
      BLPGI(K+1)=C3P(K+1)*2.0-C3P(1)
      BC5I(K+1)=C5P(K+1)*2.0-C5P(1)
 25   CONTINUE
      CALL  INVER (PA,PAI,KPMAX,LUN)
      CALL  INVER (BLPG,BLPGI,KPMAX,LUN)
```

```
      CALL INVER (BC5,BC5I,KPMAX,LUN)
      DO 40 K=1,KPMAX
      WRITE (LUN,29) PA(K),BLPG(K),BC5(K)
   29 FORMAT (30X,"BBL / BCF",3(10X,E14.6))
   40 CONTINUE
      RETURN
      END
      SUBROUTINE INVER (A,AI,NP,LUN)
C    ***********************************************************************
C    *  THIS INVERTS THE ORDER OF DATA IN ONE DIMENSIONAL ARRAY             *
C    ***********************************************************************
      DIMENSION AI (30), A (30)
      DO 10  J=1,NP
      K = NP - J + 1
      A(K)=AI(J)
   10 CONTINUE
      WRITE(LUN,20) A(K)
 20   FORMAT (20X,E13.6)
      RETURN
      END
      SUBROUTINE DUM
      INTEGER TITLE
      REAL MFH2S,MFCO2,MFN2,LPG
      COMMON TITLE(26),LUN,ICODE,KPMAX,TR,PR,CTAV,CPAV,SG,PP(30),
     A ZZ(30),VISGG(30),MFH2S,MFCO2,MFN2,I,IJ,POT(30),PTAB(30),
     B ZTAB(30),UTAB(30),SALG,BLPG(10),BC5(10),PA(10),LPG,COND,P,T,
     C KP1MAX,IPL
      BLPG(6)=LPG
      BC5(6)=COND
      PA(6)=P
      BLPG(5)=0.99*LPG
      BC5(5)=0.75*COND
      PA(5)=0.85*PA(6)
      BLPG(4)=0.99*LPG
      BC5(4)=0.52*COND
      PA(4)=0.65*PA(6)
      BLPG(3)=0.98*LPG
      BC5(3)=0.47*COND
      PA(3)=0.46*PA(6)
      BLPG(2)=0.98*LPG
      BC5(2)=0.46*COND
      PA(2)=0.26*PA(6)
      BLPG(1)=0.98*LPG
      BC5(1)=0.46*COND
```

```
      PA(1)=PA(6)/1000.0
      KP1MAX=6
      CONTINUE
      RETURN
      END
      SUBROUTINE ZSTAR (CMPG)
C     ***********************************************************************
C     *    COMPRESSIBILITY FACTORS ARE CALCULATED FROM AN 11 PARAMETER    *
C     *    BWR EQUATION OF STATE,DEVELOPED BY DRANCHUK & ABOU-KASSEM      *
C     *    (1975),THAT EFFECTIVELY REPRODUCES THE STANDING-KATZ           *
C     *          Z-FACTOR CHARTS                                          *
C     ***********************************************************************
      INTEGER TITLE
      REAL MFH2S,MFCO2,MFN2,LPG
      DIMENSION A(11)
      COMMON TITLE(26),LUN,ICODE,KPMAX,TR,PR,CTAV,CPAV,SG,PP(30),
     A ZZ(30),VISGG(30),MFH2S,MFCO2,MFN2,I,IJ,POT(30),PTAB(30),
     B ZTAB(30),UTAB(30),SALG,BLPG(10),BC5(10),PA(10),LPG,COND,P,T,
     C KP1MAX,IPL
      DATA A/0.3265,-1.070,-0.5339,0.01569,-0.05165,0.5475,-0.7361,0.184
     A4,0.1056,0.6134,0.7210/
C     CALCULATE ADJUSTMENT FOR PRESENCE OF H2S & CO2
      FRCA=MFH2S+MFCO2
      FRCB=MFH2S
C     CORRECTIONS FOR THE PRESENCE OF HYDROGEN SULPHIDE &
C     CARBON DIOXIDE ARE APPLIED BY THE METHOD OF WICHERT &
C     AZIZ (1974). EPS=WICHERT & AZIZ ADJUSTMENT
      EPS=120.0*(FRCA**0.9-FRCA**1.6)+15.0*(FRCB**0.5-FRCB**4.0)
C     ADJUST PSEUDO CRITICAL TEMPERATURE & PRESSURE.
C     CALCULATE PSEUDO REDUCED TEMPERATURE & PRESSURE
      CTAVA=CTAV-EPS
      IJ=IJ+1
      IF(IJ.GT.2) GO TO 100
      GO TO 120
 100  PP(I)=P
 120  CPAVA=CPAV*CTAVA/(CTAV+FRCB*(1.0-FRCB)*EPS)
      T=T+460.0
      TR=T/CTAVA
      PR=P/CPAVA
C     *********************************************************************
C     *   SET ERROR FLAG,IERR, TO 0                                       *
C     *   CHECK UPPER AND LOWER LIMITS OF THE PARAMETERS SPECIFIED        *
C     *   BY THE FOLLOWING RANGES (INCLUSIVE)-                            *
C     *   TR - 1.05 TO 3.00                                               *
```

```
C      *   PR - 0.00 TO 15.00                                               *
C      *   FRCA - 0.00 TO 0.85                                              *
C      *   IF ANY VALUE IS OUTSIDE THE RANGE,SET IERR= 1.0,Z=0.0,           *
C      *   AND CMPG=0.0  AND RETURN TO THE MAINLINE                         *
C      *********************************************************************
       IERR=0
       IF (TR.LT.1.05.OR.TR.GT.3.00) GO TO 19
       IF (PR.LT.0.00.OR.PR.GT.15.00) GO TO 19
       IF (FRCA.LT.0.00.OR.FRCA.GT.0.85) GO TO 19
C      INITIALIZE REDUCED DENSITY AND CALCULATE COMPRESSIBILITY FACTOR
C      AND COMPRESSIBILITY  OF  THE  NATURAL GAS
       ITER=0
       J=1
       DENRD=1.0
       TR2=TR**2
       TR3=TR**3
       TR4=TR**4
       TR5=TR**5
       C1=A(7)+A(8)/TR
       C0=A(1)*TR+A(2)+A(3)/TR2+A(4)/TR3+A(5)/TR4
       C2=A(6)*TR+C1
       C3=-C1*A(9)
       C4=A(10)/TR2
       IF(PR-30.0) 1,1,22
 1     IF(TR-1.0) 2,2,3
 2     J=0
       DENRD=0.0
       DELDR=0.1
 3     IF(TR-3.0) 4,4,22
 4     DO 16 ITER=1,100
       IF(J) 5,5,6
 5     DENRD1=DENRD
       DENRD=DENRD+DELDR
 6     DENRD2=DENRD**2
       DENRD5=DENRD**5
       T1=C0*DENRD
       T2=C2*DENRD2
       T3=C3*DENRD5
       T4=C4*DENRD2
       T5=A(11)*DENRD2
       T6=EXP(-T5)
       Q=(TR+T1+T2+T3)*DENRD+T4*DENRD*(1.0+T5)*T6
       QQ=TR+2.0*T1+3.0*T2+6.0*T3+T4*T6*(3.0+3.0*T5-2.0*T5*T5)
       IF(J) 7,7,10
```

```
 7    PRCAL=Q/0.27
      IF(ABS(PRCAL-PR)-0.1E-02) 17,17,8
 8    IF(PRCAL-PR) 16,17,9
 9    DENRD=DENRD1
      DELDR=DELDR/2.0
 10   DENRD1=DENRD-(Q-0.270*PR)/QQ
      IF(DENRD1) 11,11,12
 11   DENRD1=0.5*DENRD
 12   IF(DENRD1-2.2) 14,14,13
 13   DENRD1=DENRD+0.9*(2.2-DENRD)
 14   IF(ABS(DENRD-DENRD1)-0.1E-04) 17,15,15
 15   DENRD=DENRD1
 16   CONTINUE
 17   Z=0.270*PR/(DENRD*TR)
C     COMPRESSIBILITIES ARE CALCULATED BY THE METHOD OF MATTAR,
C     BRAR, & AZIZ (1975)
      DENRD2=DENRD**2
      DENRD3=DENRD**3
      DENRD4=DENRD**4
      V1= A(1)+(A(2)/TR)+(A(3)/TR3)+(A(4)/TR4)+(A(5)/TR5)
      V2= 2.0*DENRD*(A(6)+(A(7)/TR)+(A(8)/TR2))
      V3= 4.0*DENRD4*A(9)*(A(7)/TR+(A(8)/TR2))
      V4= (2.0*A(10)*DENRD/TR3)+(4.0*A(10)*A(11)*DENRD3/TR3)
      V5= EXP(-A(11)*DENRD2)
      V6= ((A(10)*DENRD2/TR3)+(A(10)*A(11)*DENRD4/TR3))*2.0*DENRD*A(11)
      DZED= V1+V2-V3+(V4*V5)-(V6*V5)
      CMPPRD=1.0/PR-0.270*DZED/(Z*Z*TR *(1.0+(DENRD/Z)*DZED))
      CMPG  =CMPPRD /CPAVA
      GO TO 20
  19  IERR =1
      Z    =0.0
      CMPG =0
 20   WRITE (LUN,21) P,T,PR,TR,Z,CMPG,FRCA,FRCB,EPS,ITER,IERR
  21  FORMAT (9(2X,F10.6),2I3,/)
 22   PP(I)=P
      ZZ(I)=Z
      T=T-460.0
      RETURN
      END
      SUBROUTINE VISCY
C
C     ****************************************************************
C     *   THIS SUBROUTINE WILL DETERMINE THE VISCOSITY FOR NATURAL     *
C     *   GAS INCORPORATING A CORRECTION FOR THE PRESENCE OF HYDROGEN  *
```

```
C     *   SULPHIDE CARBON DIOXIDE,AND NITROGEN                             *
C     ***********************************************************************
      INTEGER TITLE
      REAL MFH2S,MFCO2,MFN2,LPG
      DIMENSION TEMTBL(13),PRSTBL(22),VISTBL(22,13),VISTBI(22,7),VISTB2(
     122,6)
      EQUIVALENCE (VISTBI(1,1),VISTBL(1,1)),(VISTB2(1,1),VISTBL(1,8))
      COMMON TITLE(26),LUN,ICODE,KPMAX,TR,PR,CTAV,CPAV,SG,PP(30),
     A ZZ(30),VISGG(30),MFH2S,MFCO2,MFN2,I,IJ,POT(30),PTAB(30),
     B ZTAB(30),UTAB(30),SALG,BLPG(10),BC5(10),PA(10),LPG,COND,P,T,
     C  KP1MAX,IPL
      DATA TEMTBL /
     11.05,1.10,1.15,1.20,1.30,1.40,1.50,1.60,1.75,2.00,2.25,2.50,3.00 /
      DATA PRSTBL /
     10.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1.0,1.2,1.4,1.6,1.8,2.0,3.0,
     24.0,6.0,8.0,10.0,15.0,20.0/
      DATA VISTBI /
     A1.000,1.012,1.025,1.050,1.075,1.100,1.145,1.195,1.285,1.415,1.760,
     B2.285,2.865,3.290,3.650,4.760,5.500,6.460,7.150,7.680,8.650,9.370,
     C1.000,1.011,1.023,1.043,1.065,1.086,1.120,1.150,1.195,1.255,1.435,
     D1.700,2.070,2.465,2.800,3.850,4.655,5.720,6.500,7.060,8.100,8.880,
     E1.000,1.010,1.021,1.036,1.055,1.073,1.095,1.120,1.145,1.175,1.280,
     F1.420,1.590,1.850,2.160,3.225,3.975,5.030,5.820,6.385,7.410,8.180,
     G1.000,1.009,1.019,1.030,1.045,1.060,1.070,1.085,1.110,1.135,1.195,
     H1.285,1.425,1.570,1.750,2.600,3.350,4.380,5.125,5.740,6.750,7.500,
     I1.000,1.008,1.017,1.027,1.040,1.054,1.063,1.075,1.100,1.120,1.155,
     J1.215,1.285,1.360,1.460,2.020,2.560,3.500,4.185,4.755,5.790,6.500,
     K1.000,1.007,1.015,1.024,1.035,1.048,1.056,1.067,1.089,1.100,1.135,
     L1.185,1.235,1.280,1.335,1.690,2.110,2.790,3.380,3.860,4.790,5.410,
     M1.000,1.006,1.013,1.021,1.030,1.042,1.049,1.059,1.078,1.100,1.120,
     N1.150,1.185,1.220,1.260,1.500,1.785,2.325,2.820,3.230,4.060,4.610/
      DATA VISTB2 /
     A1.000,1.005,1.011,1.018,1.025,1.036,1.042,1.051,1.067,1.070,1.095,
     B1.120,1.150,1.180,1.215,1.385,1.595,2.030,2.425,2.770,3.490,4.025,
     C1.000,1.004,1.009,1.015,1.021,1.030,1.035,1.043,1.056,1.065,1.090,
     D1.110,1.125,1.145,1.165,1.280,1.435,1.770,2.095,2.375,2.990,3.500,
     E1.000,1.003,1.007,1.012,1.017,1.024,1.028,1.035,1.045,1.055,1.060,
     F1.070,1.080,1.095,1.110,1.205,1.290,1.500,1.725,1.955,2.480,2.925,
     G1.000,1.002,1.005,1.009,1.013,1.018,1.021,1.027,1.034,1.040,1.045,
     H1.055,1.065,1.075,1.085,1.145,1.210,1.340,1.485,1.665,2.085,2.460,
     I1.000,1.001,1.003,1.006,1.009,1.012,1.015,1.019,1.023,1.025,1.030,
     J1.040,1.050,1.060,1.065,1.105,1.155,1.245,1.360,1.485,1.830,2.150,
     K1.000,1.000,1.001,1.003,1.005,1.007,1.009,1.011,1.013,1.015,1.020,
     L1.025,1.030,1.035,1.040,1.060,1.085,1.140,1.205,1.265,1.495,1.750/
```

```
C     INITIALISE UPPER AND LOWER BOUNDS FOR THE TABLES OF PSEUDO REDUCED
C     TEMPERATURE AND PRESSURE INDEXES
C     -  ERROR  FLAG, IERR,TO 0
      LOPRS=2
      IHIPRS=21
      LOTEM =3
      IHITEM=11
      IERR1  =0
C     CHECK UPPER AND LOWER LIMITS OF THE PARAMETERS SPECIFIED BY THE
C     FOLLOWING INCLUSIVE RANGES
      IF (TR.LT.1.05.OR.TR.GT.3.00) GO TO 340
      IF (PR.LT.0.01.OR.PR.GT.20.0) GO TO 340
      IF (SG.LT.0.55.OR.SG.GT.1.50) GO TO 340
C     LOCATE TR IN THE TEMP INDEX
      DO 100 J=LOTEM,IHITEM
      IF(TEMTBL(J).GE.TR)GO TO 120
  100 CONTINUE
      J= IHITEM+1
  120 IF(PRSTBL(LOPRS-1).LT.PR) GO TO 160
      K=1
      ICALL=1
      GO TO 320
  140 VISGR=1.00+(PR*(VISI-1.0))
      GO TO 300
  160 IF(PRSTBL(IHIPRS+1).GT.PR) GO TO 200
      K=IHIPRS+1
      ICALL=2
      GO TO 320
  180 VISGR=VISI
      GO TO 300
  200 DO 220 K=LOPRS,IHIPRS
      IF(PRSTBL(K).GE.PR) GO TO 240
  220 CONTINUE
      K=IHIPRS +1
  240 ICALL =3
      GO TO 320
  260 VISJ=VISI
      K=K-1
      ICALL=4
      GO TO 320
  280 K=K+1
      VISGR=VISI+(((PR-PRSTBL(K-1))/(PRSTBL(K)-PRSTBL(K-1)))*(VISJ-VISI)
     A)
C     CALCULATE PARTIAL VISCOSITY,VISGU. MODIFY THE VALUE BY APPLYING
```

```
C       CORRECTIONS DEPENDENT UPON THE MOL FRACTIONS OF H2S,CO2, & N2
C       TO OBTAIN THE PARTIAL VISCOSITY AT 1 ATM PRESSURE,VISGA
C       CALCULATE THE OVERALL VISCOSITY,VISG
 300    VISGU=(0.126585E-01)-(0.611823E-02)*SG+(0.164574E-02)*SG*SG
       A+(0.164574E-04)*T-(0.719221E-06)*SG*T-(0.609046E-06)*SG*SG*T
        CORH2S=(0.0113*MFH2S*SG-0.0038*MFH2S+0.000001)*
       A(1.0/(1.0+SG))+0.000001
        CORCO2=(0.0134*MFCO2*SG-0.0004*MFCO2+0.000004*SG)
       A *(1.0/(1.0+SG))-0.000003
        CORN2 =(0.0170*MFN2*SG+0.0021*MFN2 +0.000010*SG)
       A *(1.0/(1.0+SG))-0.000006
        VISGA =VISGU +CORH2S+CORCO2+CORN2
        VISG =VISGR* VISGA
        GO TO 354
C       CALL TO LAGRANGE INTERPOLATION ROUTINE
  320   CALL XLGR4 (TR,TEMTBL(J-2),TEMTBL(J-1),TEMTBL(J),
       A TEMTBL(J+1),VISI,VISTBL(K,J-2),VISTBL(K,J-1),
       B VISTBL(K,J),VISTBL(K,J+1))
        WRITE (LUN,351) VISI
 351    FORMAT (2X,E8.6)
        GO TO (140,180,260,280),ICALL
C       DATA ERROR PROCEDURE
  340   IERR1=1
        VISGR=0.0
        VISG =0.0
 354    WRITE (LUN,355) T,TR,PR,VISG,VISGA,VISGU,SG,CORH2S,CORCO2,CORN2,
       1 IERR1,ICALL
  355   FORMAT (10(2X,E8.6),2I3,/)
 356    VISGG(I)=VISG
  360   RETURN
        END
        SUBROUTINE XLGR4 (X,X1,X2,X3,X4,Y,Y1,Y2,Y3,Y4)
C       ******************************************************************
C       *   THIS SUBROUTINE EVALUATES THE GENERAL LAGRANGE EQUATION      *
C       *   (K.L.NEILSON,METHODS IN NUMERICAL ANALYSIS,1956,FOR A Y      *
C       *   VALUE CORRESPONDING TO A GIVEN X VALUE LYING WITHIN THE      *
C       *   RANGE OF FOUR GIVEN POINTS: (X1,Y1),(X2,Y2),(X3,Y3),(X4,Y4)  *
C       ******************************************************************
        A1 =X1-X2
        A2 =X1-X3
        A3 =X1-X4
        A4 =X2-X3
        A5 =X2-X4
        A6 =X3-X4
```

```
      B1 =X-X1
      B2 =X-X2
      B3 =X-X3
      B4 =X-X4
      Y  =B2/A1*B3/A2*B4/A3*Y1-B1/A1*B3/A4*B4/A5*Y2+B1/A2*B2/A4*B4/A6
     1*Y3-B1/A3*B2/A5*B3/A6*Y4
      RETURN
      END
      SUBROUTINE TERP (A, B, Y, X, KMAX,LUN)
C     STRAIGHT LINE INTERPOLATION (INCLUDING Y=0 TO Y(I)
C          FOR X=0 TO X(I)
C     A IS UNKNOWN VALUE OF Y AT X = B
      DIMENSION Y(30),X(30)
      K=1
      IF(B.LT.0.0)GO TO 12
      IF (B- X(1))1,2,2
    1 A = Y(1)* B / X(1)
      GO TO 20
    2 CONTINUE
      IF (X(KMAX)- B)12,3,4
   12 WRITE(6,9) X(KMAX),B
      STOP 5
    3 A = Y(KMAX)
      GO TO 20
   11  IF((X(KMAX)-B).LE.0.0)GO TO 12
      K=K+1
    4 IF (X(K)- B) 5,6,7
    5 GO TO 11
    6 A= Y(K)
      GO TO 20
    7 A= Y(K-1) + (Y(K)-Y(K-1))*(B-X(K-1)) / (X(K)-X(K-1))
      GO TO 20
    9 FORMAT(15X,"VALUE BEYOND TABLE, KMAX =",E14.6,//,38X,"B="E14.6)
   20 CONTINUE
      WRITE (LUN,22) A,B
  22  FORMAT (2X,2(E13.6))
      RETURN
      END
      SUBROUTINE QINTE  (A, Y, X, N,LUN)
C    **********************************************************************
C     AREA UNDER CURVE Y = FUNCTION OF X VERSUS Y TO K= N
C    *       CALCULATED FROM X=0 TO Y=0
C    **********************************************************************
      DIMENSION A(30),Y(30),X(30)
```

```
      A(1)=0.0
      A(2) = 0.5 * Y(2) * X(2)
      WRITE (LUN,30)X(1)
30    FORMAT (E8.6)
      DO 10  K = 3, N
      A(K) = 0.5 *(Y(K)+Y(K-1))*(X(K)-X(K-1)) + A(K-1)
   10 CONTINUE
      WRITE(LUN,20) A(N)
20    FORMAT (E13.6)
      RETURN
      END
      SUBROUTINE ZMPL (NP,TITLE,PTAB,ZTAB,UTAB,POT)
      INTEGER TITLE
      DIMENSION TITLE(26),PTAB(30),ZTAB(30),UTAB(30),IBUF(40),
     A IYP(20),IXZ(20),IXU(20),IXPOT(22),POT(30)
      CALL CODE
      WRITE (IYP,1)
1     FORMAT ("RESERVOIR PRESSURE (PSIA 10E+4)")
      CALL CODE
      WRITE (IXZ,2)
2     FORMAT("DEVIATION FACTOR -Z")
      CALL PLOTS (38.0,10.0,0,-1.0,-1.0)
      CALL PLOT (5.5,5.0,-3)
      CALL SYMB (0.0,0.0,5.0,7,90.0,-1)
      CALL PLOT (13.5,-4.0,-3)
      CALL AXIS (0.0,0.0,IXZ,19,7.0,180.0,0.75,0.05)
      CALL AXIS (0.0,0.0,IYP,-31,8.0,90.0,0.0,0.08)
      IPEN=3
      DO 100 I=1,NP
      Y=PTAB(I)/800.0
      X=-((ZTAB(I)-0.75)*20.0)
      CALL PLOT (X,Y,IPEN)
      CALL SYMB (X,Y,0.1,3,0.0,-1)
      IPEN=2
 100  CONTINUE
      CALL CODE
      WRITE (IBUF,3)(TITLE(J),J=1,26)
 3    FORMAT (20A2,10X,2A2,2X,4A2)
      CALL SYMB(-6.0,2.0,0.1,IBUF,90.0,64)
      CALL PLOT (8.5,0.0,-3)
      CALL CODE
      WRITE (IXU,4)
 4    FORMAT (" VISCOSITY-U (CP 10E-1)")
      CALL AXIS (0.0,0.0,IXU,23,7.0,180.0,0.1,0.03)
```

```
      CALL AXIS (0.0,0.0,IYP,-31,8.0,90.0,0.0,0.08)
      IPEN=3
      DO 200 I=1,NP
      Y=PTAB(I)/800.0
      X=-((UTAB(I)-0.01)*333.333)
      CALL PLOT (X,Y,IPEN)
      CALL SYMB (X,Y,0.1,3,0.0,-1)
      IPEN=2
 200  CONTINUE
      CALL SYMB (-6.0,2.0,0.1,IBUF,90.0,64)
      CALL PLOT (8.5,0.0,-3)
      CALL CODE
      WRITE (IXPOT,5)
 5    FORMAT ("GAS POTENTIAL-PHI (PSIA SQUARED/CPS/10E+10)")
      CALL AXIS (0.0,0.0,IXPOT,43,7.0,180.0,0.0,0.03)
      CALL AXIS (0.0,0.0,IYP,-31,8.0,90.0,0.0,0.08)
      IPEN=3
      DO 300 I=1,NP
      Y=PTAB(I)/800.0
      X=-(POT(I)/1.0E+10*33.3333)
      CALL PLOT (X,Y,IPEN)
      CALL SYMB (X,Y,0.1,3,0.0,-1)
      IPEN=2
 300  CONTINUE
      CALL SYMB (-6.0,2.0,0.1,IBUF,90.0,64)
      CALL PLOT (0.0,0.0,999)
      CALL GOPLT
      RETURN
      END
      PROGRAM GAS3(5)
C++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
      REAL KH,MFH2S,MFCO2,MFN2,LPG
      INTEGER TITLE
      DIMENSION Q2(40),GP(40),GP1(40),GPLPG(40),GPCON(40),SUMGP(40),
     A SUMLPG(40),SUMCON(40),QOVOL(40),PTF(40),PWF(40),PB(40),
     B BLP(40),BCO(40),SUMGP1(40)
      COMMON TITLE(26),LUN,ICODE,KPMAX,TR,PR,CTAV,CPAV,SG,PP(30),
     A ZZ(30),VISGG(30),MFH2S,MFCO2,MFN2,I,IJ,POT(30),PTAB(30),
     B ZTAB(30),UTAB(30),SALG,BLPG(10),BC5(10),PA(10),LPG,COND,P,T,
     C KP1MAX,IPL
      IF(ICODE.EQ.1) GO TO 9998
      READ(5,*) VOL,POR,SATW,AVETH
      READ (5,*)NYRMAX,NW,MAR
```

```
      READ (5,*)RW,KH,S,DTURB
      READ (5,*)Q,QMIN,THPMIN,QOVER
      READ (5,*) TBGEL,TBGDIA,FR,FAC,TEMTOP,IEND
      PRESSI=PP(1)
      IF(IEND.NE.-1) GO TO 1
      WRITE (6,81)( TITLE (J),J=1,26)
   81 FORMAT (1H1,5/, 40X,20A2,22X,2A2,5X,4A2,1(/))
      WRITE (6,400) VOL,POR,SATW,AVETH,T,PRESSI
  400 FORMAT(113X,"PAGE 1",/,
     * 46X ,"DELIVERABILITY  PARAMETERS",/,46X,"--------------",2X,
     A"----------",3(/),5X,"RESERVOIR DATA",/,5X,"--------- ----",/,19X,
     B"VOLUME OF GAS INITIALLY IN PLACE",25X,F11.0,6X,"(MMSCF)",/,19X,
     C"POROSITY",53X,F11.4,2X,"(FRACTION)",/,19X,"WATER SATURATION",45X,
     DF11.4,2X,"(FRACTION)",/,19X,"AVERAGE THICKNESS OF RESERVOIR",31X,
     EF11.4,2X,"(FT)",/,19X,"INITIAL RESERVOIR TEMPERATURE",28X,F11.0,
     F6X,"(DEGREES F)",/,19X,"INITIAL RESERVOIR PRESSURE",31X,F11.0,6X,
     G"(PSIA)",2(/))
      WRITE (6,401)RW,KH,S,DTURB,TBGEL,TBGDIA,FR,FAC,TEMTOP
  401 FORMAT(5X,"WELL DATA",/,5X,"---- ----",/,19X,"WELL RADIUS",50X,
     AF11.4 2X,"(FT)",/,19X,"PERMEABILITY*THICKNESS",39X,F11.4,2X,"(MDS-
     BFT)",/,19X,"SKIN FACTOR",48X,F11.2,2X,/,19X,"TURBULENCE FACTOR",
     C 44X,F11.4,2X,"(D/MMSCF)",/,19X,"TUBING ELEVATION",
     D" (TRUE VERTICAL DEPTH)",19X,F11.0,6X,"(FT)",/,19X,"TUBING ",
     E"DIAMETER",46X,F11.4,2X,"(IN)",/,19X,"FRICTION FACTOR",46X,F11.4,/,
     F19X,"ACTUAL LENGTH / TRUE VERTICAL DEPTH FACTOR",19X,F11.4,/,19X,
     G"TEMPERATURE OF GAS AT SURFACE IN TUBING",18X,F11.0,6X,"(DEGREES F
     H)",2(/))
      WRITE (6,402) Q,NW,QOVER,THPMIN,QMIN
  402 FORMAT(5X,"ASSUMED REQUIREMENTS",/,5X,"------- ------------",/,
     A19X,"INITIAL RAW GAS PRODUCTION RATE",30X,F11.4,2X,"(MMSCF/D/WELL)
     B",/,19X,"NUMBER OF PRODUCING WELLS",39X,I3,/,19X,"PEAK PRODUCTION",
     C " RATE / PRODUCTION RATE",23X,F11.4,2X,"(RATIO)",/,19X,"MINIMUM",
     D" TUBING HEAD PRESSURE",29X,F11.0,6X,"(PSIA)",/,19X,"MINIMUM (OR C
     EUT-OFF) PRODUCTION RATE",25X,F11.4,2X,"(MMSCF/D/WELL)",2(/))
      WRITE(6,403)
  403 FORMAT(5X,"DEFINITIONS",/,5X,"-----------",/,19X,"SALES GAS - METH
     1ANE,ETHANE, AND UP TO 3% CARBON DIOXIDE",/,19X,"LPG - PROPANE AND
     2BUTANES",/,19X,"CONDENSATE - PENTANES PLUS")
      WRITE (LUN,84) VOL,POR,SATW,AVETH,T,PRESSI
      WRITE (LUN,85)NYRMAX,NW,NP
      IF(KPMAX.EQ.0) GO TO 184
      GO TO 185
  184 KPMAX=KP1MAX
  185 CONTINUE
```

```
      WRITE (LUN,84)(PTAB (M),M=1,NP)
      WRITE (LUN,84)(ZTAB (M),M=1,NP)
      WRITE (LUN,84)(UTAB (M),M=1,NP)
      WRITE (LUN,84)RW, KH,S
      WRITE (LUN,84)Q,QMIN,THPMIN,QOVER
      WRITE (LUN,84)TBGEL,TBGDIA,FR,FAC,TEMTOP,IEND
   84 FORMAT (2X,10F11.4)
   85 FORMAT (20I5)
      GO TO 3
  1   WRITE (6,2)
  2   FORMAT(10X,"DATA TAPE INCORRECT")
      STOP 6
  3   NP=I
      TSC = 60.
      PSC = 14.73
      CUMQ1=0.0
      DO 86 N=1,40
      GP(N)=0.0
      GPLPG(N)=0.0
      GPCON(N)=0.0
  86  CONTINUE
      CALL TERP (ZI, PRESSI, ZTAB, PTAB,NP,LUN)
      BI = ZI * (T + 460.) * PSC / (TSC + 460.) / PRESSI
      RE = VOL * BI / POR / (1. - SATW) / AVETH / NW / 3.14159
      RE = 1000. * SQRT(RE)
      CONTINUE
      C4 = 0.472 * RE / RW
      C4 = ALOG(C4) + S
      CONTINUE
      ZBAR = ZI
      N = 0
C    ***************************************************************************
C    *         START CALCULATING ANNUAL PERFORMANCE                            *
C    ***************************************************************************
    5 N = N+1
      CUMQ2=CUMQ1
C    ***************************************************************************
C    * TEST FOR FINAL YEAR FOR MINIMUM DAILY GROSS GAS PRODUCTION              *
C    *    AND CALCULATE PARAMETERS FOR NEXT YEAR                               *
C    ***************************************************************************
      IF(N.GT.NYRMAX) GO TO 9000
      GO TO 118
 18   Q=0.98*Q
      IF(Q.LE.0.98*QMIN) Q=0.0
```

```
 118  CUMQ1= CUMQ2 + 365.* Q * FLOAT(NW)
      QOVOL1=CUMQ1 / VOL
      PBAR = ZBAR * PRESSI * (1. - QOVOL1) / ZI
      CALL TERP (ZBAR, PBAR, ZTAB , PTAB,NP,LUN)
      PBAR1= ZBAR * PRESSI * (1. - QOVOL1) / ZI
      WRITE (LUN,310) PBAR1,QOVOL1,Q
 310  FORMAT (3(2X,E13.6))
C     CALCULATION OF GAS FLOW IN RESERVOIR
      CALL TERP (POTBAR, PBAR1,POT, PTAB, NP,LUN)
      Q1 = Q * QOVER
      C44=C4+DTURB*Q1
      C44=((T+460.0)*C44/KH/0.7)*1000000.0
      WRITE(LUN,302) RE,DTURB,C44
 302  FORMAT (20X,"RE=",E14.6,20X,"DTURB=",E14.6,20X,"C44=",E14.6)
      POTPWF = (POTBAR - (C44* Q1))
      IF(POTPWF.LE.0.0)GO TO 18
      CALL TERP (PWF1,POTPWF, PTAB, POT, NP,LUN)
C     CALCULATION OF FLOW IN TUBING
C     R.V.SMITH MODIFIED WEYMOUTH EQUATION,"HANDBOOK OF NATURAL GAS
C     ENGINEERING" BY KATZ ET. AL.(1959,P 309)
      TA = (T + TEMTOP)/2.0 + 460.
      ZA1= 0.90
      J = 1
  19  S1 = 0.0375 * SG * TBGEL / TA / ZA1
      A1 = (TBGDIA)** 5.0 / SG / TA / ZA1 / FR / TBGEL / FAC
      E1 = EXP (S1)
      PTFPTF= (((1.-E1)/S1 * 25.0 / A1)* Q1* Q1+  PWF1* PWF1)
     A   /E1
      IF(PTFPTF.LT.0.0) GO TO 18
      PTF1=SQRT(PTFPTF)
      WRITE (LUN,304) ZA1,S1,A1,E1,PTF1
 304  FORMAT (2X,5(E13.6))
      IF(J-3) 11,12,12
   11 J = J + 1
      CALL TERP (ZA1, PTF1,ZTAB, PTAB, NP,LUN)
      GO TO 19
   12 CONTINUE
      IF((PTF1- THPMIN).LT.0.0) GO TO 18
C    ****************************************************************
C    * FILL ARRAYS FOR YEAR N AND GO TO NEXT N                      *
C    ****************************************************************
   90 Q2 (N) = Q
      GP1(N) = Q * 365. * FLOAT(NW)/1000.
      IF(PA(KPMAX)-PRESSI) 142,143,143
```

```
 142 WRITE (6,144)PA(KPMAX),PRESSI
 144 FORMAT (15X,"PA(KPMAX) = ",E14.6,15X,"PRESSI = "E14.6)
     PA(KPMAX)=PRESSI
 143 CALL TERP (BLP(N),PBAR1,BLPG,PA,KPMAX,LUN)
     CALL TERP (BCO(N),PBAR1,BC5,PA,KPMAX,LUN)
     GP(N)=GP1(N)*SALG
     IF(N.GT.1)GO TO 43
     SUMGP(1)= GP(1)
     GPLPG(1)=BLP(1)*GP1(1)
     GPCON(1)=BCO(1)*GP1(1)
     SUMLPG(1)=GPLPG(1)/1000.0
     SUMCON(1)= BCO(1)*GP1(1)/1000.0
     GO TO 42
43   GPLPG(N)=BLP(N)*GP1(N)
     GPCON(N)=BCO(N)*GP1(N)
     SUMGP(N)=SUMGP(N-1)+GP(N)
     SUMLPG(N)=SUMLPG(N-1)+GPLPG(N)/1000.0
     SUMCON(N)=SUMCON(N-1)+GPCON(N)/1000.0
     IF(Q2(N).LE.0.0) GPLPG(N)=0.0
     IF(Q2(N).LE.0.0) GPCON(N)=0.0
42   QOVOL (N) = QOVOL1
     PTF (N)    = PTF1
     PWF (N)    = PWF1
     PB(N)  = PBAR1
     GO TO 5
9000 WRITE(6,81)(TITLE(J),J=1,26)
     WRITE (6,9010)
9010 FORMAT (113X,"PAGE 4",/,
    *        15X, "RATE", 11X, "ANNUAL PRODUCTION", 11X, "CUMULATIVE ",
    1"PRODUCTION", 21X, "PRESSURES  (PSIA)")
9020 WRITE (6,9030)
9030 FORMAT (8X, "YR", 5X, "PER",  9X, "------------------------",
    17X,"------------------------", 16X, "------------------------")
9040 WRITE (6,9050)
9050 FORMAT (15X, "WELL", 8X, "SALES", 5X, "LPG", 6X, "COND", 7X,
    1"SALES",5X, "LPG",7X, "COND", 6X, "FRAC", 6X, "TOP", 7X, "BOT",
    27X, "RES")
9060 WRITE (6,9070)
9070 FORMAT (15X, "RAW GAS", 5X, "GAS", 6X, "MBBL", 6X,"MBBL", 7X,
    1"GAS", 6X, "MMBBL", 5X, "MMBBL", 6X, "PROD",/ ,15X,"MMCFD",7X,
    2"BCF",27X,"BCF",/)
9080 DO 9900  N = 1, NYRMAX
9090 WRITE (6,9100) N, Q2(N), GP(N), GPLPG(N), GPCON(N), SUMGP(N), SUML
    1PG(N), SUMCON(N), QOVOL(N), PTF(N), PWF(N), PB(N)
```

```
9100 FORMAT (8X,I2,F10.2,1X,3(1X,F9.2),1X,F9.2,2(1X,F9.3),1X,F9.4,3(1X,
    A F9.1))
9900 CONTINUE
     IF (IPL .NE.1) GO TO 9998  .
9905 CONTINUE
     CALL PZPL (NP,N,NYRMAX,QOVOL,Q2,PTF,PB)
7502 CALL TPLOT (N,NYRMAX,SUMGP,GP,PWF,PB,BLP,BCO)
9998 CONTINUE
      STOP 7
9999 CALL GAS1
     END
     SUBROUTINE TERP (A, B, Y, X, KMAX,LUN)
C    A IS UNKNOWN VALUE OF Y AT X = B
     DIMENSION Y(30),X(30)
     K=1
     IF(B.LT.0.0)GO TO 12
     IF (B- X(1))1,2,2
   1 A = Y(1)* B / X(1)
     GO TO 20
   2 CONTINUE
     IF (X(KMAX)- B)12,3,4
  12 WRITE(6,9) X(KMAX),B
     STOP 10
   3 A = Y(KMAX)
     GO TO 20
  11 IF((X(KMAX)-B).LE.0.0) GO TO 12
     K=K+1
   4 IF (X(K)- B) 5,6,7
   5 GO TO 11
   6 A= Y(K)
     GO TO 20
   7 A= Y(K-1) + (Y(K)-Y(K-1))*(B-X(K-1)) / (X(K)-X(K-1))
     GO TO 20
   9 FORMAT(15X,"VALUE BEYOND TABLE, KMAX =",E14.6,//,38X,"B="E14.6)
  20 CONTINUE
     WRITE (LUN,22) A,B
 22  FORMAT (2X,2(E13.6))
     RETURN
     END
     SUBROUTINE PZPL(NP,N,NYRMAX,QOVOL,Q2,PTF,PB)
     INTEGER TITLE
     REAL MFH2S,MFCO2,MFN2,LPG
     COMMON TITLE (26),LUN,ICODE,KPMAX,TR,FR,CTAV,CPAV,SG,PP(30),
    A ZZ(30),VISGG(30),MFH2S,MFCO2,MFN2,I,IJ,POT(30),PTAB(30),
```

```
     B ZTAB(30),UTAB(30),SALG,BLPG(10),BC5(10),PA(10),LPG,COND,P,T,
     C KP1MAX,IPL
      DIMENSION IBUF(40),IYP(20),
     A IYT(20),IXQO(20),IXQ2(20),IXPTF(20),
     B QOVOL(40),Q2(40),SUMGP(40),PTF(40),PB(40)
      CALL PLOTS (47.0,10.0,0,-1.0,-1.0)
      CALL PLOT (5.5,5.0,-3)
      CALL SYMB (0.0,0.0,5.0,7,90.0,-1)
      CALL PLOT (13.5,-4.0,-3)
      CALL CODE
      WRITE (IBUF,3)(TITLE(J),J=1,26)
3     FORMAT (20A2,10X,2A2,2X,4A2)
      IF(NYRMAX-24) 7800,7801,7802
7800  SCAL=2.0
      GO TO 7803
7801  SCAL=3.0
      GO TO 7803
7802  SCAL=5.0
7803  CALL PLOT (8.5,0.0,-3)
      CALL CODE
      WRITE (IYT,6)
6     FORMAT("TIME (YRS)")
      CALL CODE
      WRITE (IXQO,7)
7     FORMAT("FRACTION OF GAS PRODUCED")
      CALL CODE
      WRITE (IYP,9)
9     FORMAT ("RESERVOIR PRESSURE (PSIA 10E+4)")
      CALL AXIS (0.0,0.0,IXQO,24,5.0,180.0,0.0,0.2)
      CALL AXIS (0.0,0.0,IYT,-10,8.0,90.0,0.0,SCAL)
      IPEN=3
      DO 400 I=1,NYRMAX
      Y=I/SCAL
      X=-(QOVOL(I)*5.0)
      CALL PLOT (X,Y,IPEN)
      IPEN=2
400   CONTINUE
      CALL PLOT (0.0,0.0,3)
      Y=1/SCAL
      X=-(QOVOL(1)*5.0)
      CALL PLOT (X,Y,2)
      CALL SYMB (-5.0,2.0,0.1,IBUF,90.0,64)
      CALL PLOT (8.5,0.0,-3)
      CALL AXIS (0.0,0.0,IXQO,24,5.0,180.0,0.0,0.2)
```

```
      CALL AXIS (0.0,0.0,IYP,-31,8.0,90.0,0.0,0.08)
      IPEN=3
      DO 1000 I=1,NYRMAX
      Y=PB(I)/800.0
      X=-(QOVOL(I)*5.0)
      CALL PLOT (X,Y,IPEN)
      IPEN=2
1000  CONTINUE
      CALL SYMB (-6.0,2.0,0.1,IBUF,90.0,64)
      CALL PLOT (8.6,0.0,-3)
      CALL CODE
      WRITE (IXQ2,8)
8     FORMAT ("RAW GAS PRODUCTION (MMCFD/WELL)")
      CALL CODE
      WRITE(IXPTF,10)
10    FORMAT ("TUBING HEAD PRESSURE (PSIA 10E+3)")
      IF(Q2(1)-7.0) 6800,6800,6801
6800  QSCAL=1.0
      GO TO 6802
6801  QSCAL=10.0
6802  IF(PTF(1)-560.0) 6900,6900,6901
6900  PSCAL=0.08
      GO TO 6902
6901  PSCAL=0.8
6902  CALL AXIS (0.0,0.0,IXQ2,31,7.0,180.0,0.0,QSCAL)
      CALL AXIS (0.0,0.0,IYT,-10,8.0,90.0,0.0,SCAL)
      CALL AXIS (0.0,8.0,IXPTF,-33,7.0,180.0,0.0,PSCAL)
      IPEN=3
      DO 500 I=1,NYRMAX
      Y=I/SCAL
      X=-(Q2(I)/QSCAL)
      CALL PLOT (X,Y,IPEN)
      IPEN=2
500   CONTINUE
      X=-(Q2(1)/QSCAL)
      CALL PLOT (X,0.0,3)
      Y=1/SCAL
      CALL PLOT (X,Y,2)
      IPEN=3
      DO 1100 I=1,NYRMAX
      Y=I/SCAL
      X=-(PTF(I)/PSCAL/1000.0)
      CALL PLOT (X,Y,IPEN)
      IPEN=2
```

```
      CALL SYMB (X,Y,0.1,7,0.0,-1)
1100  CONTINUE
      CALL SYMB (-6.5,8.4,0.1,7,0.0,-1)
      CALL SYMB (-6.0,1.0,0.1,IBUF,90.0,64)
999   CONTINUE
      CALL PLOT (0.0,0.0,999)
      CALL GOPLT
      RETURN
      END
      SUBROUTINE TPLOT (N,NYRMAX,SUMGP,GP,PWF,PB,BLP,BCO)
      INTEGER TITLE
      REAL MFH2S,MFCO2,MFN2,LPG
      COMMON TITLE(26),LUN,ICODE,KPMAX,TR,PR,CTAV,CPAV,SG,PP(30),
     A ZZ(30),VISGG(30),MFH2S,MFCO2,MFN2,I,IJ,POT(30),PTAB(30),
     B ZTAB(30),UTAB(30),SALG,BLPG(10),BC5(10),PA(10),LPG,COND,P,T,
     C KP1MAX,IPL
      DIMENSION IBUF(40),IYT(20),IXSGP(20),IXPB(20),PB(40),SUMGP(40),
     A IXPWF(20),PWF(40),IXBLP(20),IXBCO(20),BLP(40),BCO(40),IYP(20),
     B IXGP(20),GP(40)
      CALL CODE
      WRITE (IYT,1)
1     FORMAT ("TIME (YRS)")
      IF(NYRMAX-24) 7800,7801,7802
7800  SCAL=2.0
      GO TO 7803
7801  SCAL=3.0
      GO TO 7803
7802  SCAL=5.0
7803  CALL CODE
      WRITE (IBUF,3) (TITLE(J),J=1,26)
3     FORMAT (20A2,10X,2A2,2X,4A2)
      CALL PLOTS (57.0,10.0,0,-1.0,-1.0)
      CALL PLOT (5.5,5.0,-3)
      CALL SYMB (0.0,0.0,5.0,7,90.0,-1)
      CALL PLOT (13.5,-4.0,-3)
      CALL CODE
      WRITE (IXGP,9)
9     FORMAT ("ANNUAL SALES GAS PRODUCTION (BCF)")
      IF(GP(1)-70.0) 5600,5600,5601
5600  GSCAL=10.0
5601  GSCAL=100.0
5602  CALL AXIS (0.0,0.0,IXGP,33,7.0,180.0,0.0,GSCAL)
      CALL AXIS (0.0,0.0,IYT,-10,8.0,90.0,0.0,SCAL)
      IPEN=3
```

```
      DO 600 I=1,NYRMAX
      Y=I/SCAL
      X=-(GP(I)/100.0)
      CALL PLOT (X,Y,IPEN)
      IPEN=2
600   CONTINUE
      X=-(GP(1)/100.0)
      CALL PLOT (X,0.0,3)
      Y=1.0/SCAL
      CALL PLOT (X,Y,2)
      CALL SYMB(-6.0,2.0,0.1,IBUF,90.0,64)
      CALL PLOT (8.6,0.0,-3)
      CALL CODE
      WRITE (IXSGP,10)
10    FORMAT ("CUMULATIVE SALES GAS (TCF)")
      CALL AXIS (0.0,0.0,IXSGP,26,7.0,180.0,0.0,1.5)
      CALL AXIS (0.0,0.0,IYT,-10,8.0,90.0,0.0,SCAL)
      IPEN=3
      DO 700 I=1,NYRMAX
      Y=I/SCAL
      X=-((SUMGP(I)/3000.0)*2.0)
      CALL PLOT (X,Y,IPEN)
      IPEN=2
700   CONTINUE
      CALL PLOT (0.0,0.0,3)
      Y=1/SCAL
      X=-((SUMGP(1)/3000.0)*2.0)
      CALL PLOT (X,Y,2)
      CALL SYMB (-6.0,2.0,0.1,IBUF,90.0,64)
      CALL PLOT (8.5,0.0,-3)
      CALL CODE
      WRITE (IXPWF,11)
11    FORMAT ("FLOWING BOTTOM PRESSURE (PSIA 10E+3)")
      CALL AXIS (0.0,0.0,IXPWF,36,7.0,180.0,0.0,1.0)
      CALL AXIS (0.0,0.0,IYT,-10,8.0,90.0,0.0,SCAL)
      IPEN=3
      DO 800 I=1,NYRMAX
      Y=I/SCAL
      X=-(PWF(I)/1000.0)
      CALL PLOT (X,Y,IPEN)
      IPEN=2
800   CONTINUE
      CALL SYMB (-6.0,2.0,0.1,IBUF,90.0,64)
801   CALL PLOT (8.5,0.0,-3)
```

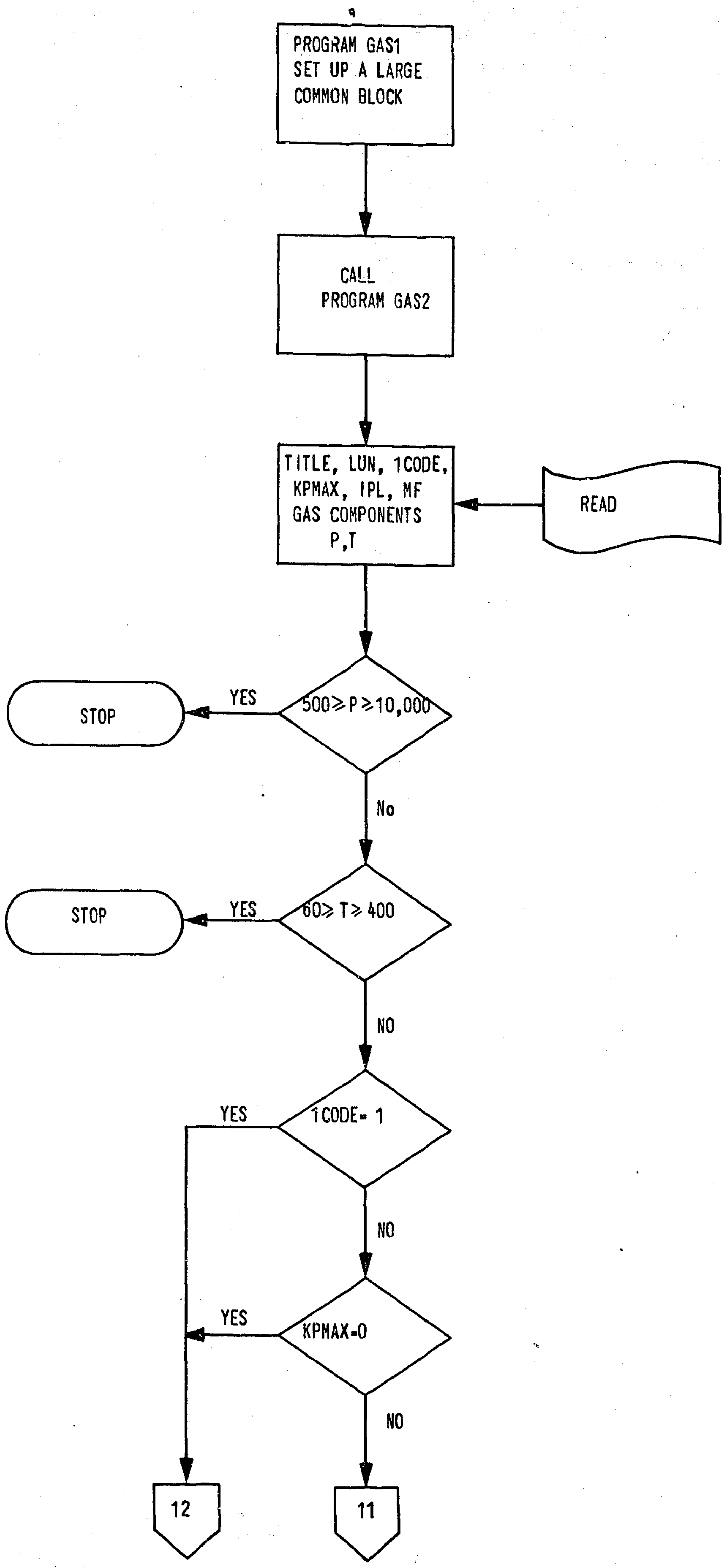
```
      CALL CODE
      WRITE (IXPB,12)
12    FORMAT ("RESERVOIR PRESSURE (PSIA 10E+3)")
      CALL AXIS (0.0,0.0,IXPB,31,7.0,180.0,0.0,1.0)
      CALL AXIS (0.0,0.0,IYT,-10,8.0,90.0,0.0,SCAL)
      IPEN=3
      DO 900 I=1,NYRMAX
      Y=I/SCAL
      X=-(PB(I)/1000.0)
      CALL PLOT (X,Y,IPEN)
      IPEN=2
900   CONTINUE
      X=-(PP(1)/1000.0)
      CALL PLOT (X,0.0,3)
      Y=1/SCAL
      X=-(PB(1)/1000.0)
      CALL PLOT (X,Y,2)
      CALL SYMB (-6.0,2.0,0.1,IBUF,90.0,64)
      CALL PLOT (8.5,0.0,-3)
      CALL CODE
      WRITE (IXBLP,13)
13    FORMAT ("LPG (BBLS/MMCF)")
      CALL CODE
      WRITE (IXBCO,14)
14    FORMAT ("COND (BBLS/MMCF)")
      CALL CODE
      WRITE (IYP,15)
15    FORMAT ("PRESSURE (PSIA 10E+4)")
      IF(BLP(1)-35.0) 6800,6800,6801
6800  BLSCAL=5.0
      GO TO 6802
6801  BLSCAL=40.0
6802  CALL AXIS (0.0,0.0,IXBLP,15,7.0,180.0,0.0,BLSCAL)
      IF(BCO(1)-35.0) 5800,5800,5801
5800  BCSCAL=5.0
      GO TO 6803
5801  BCSCAL=40.0
6803  CALL AXIS (0.0,0.0,IYP,-21,8.0,90.0,0.0,0.08)
      CALL AXIS (0.0,8.0,IXBCO,-16,7.0,180.0,0.0,BCSCAL)
      IPEN=3
      DO 1000 I=1,NYRMAX
      Y=PB(I)/800.0
      X=-BLP(I)/BLSCAL
      WRITE (LUN,1120) X,Y,BLP(I),BCO(I),BLSCAL,BCSCAL
```

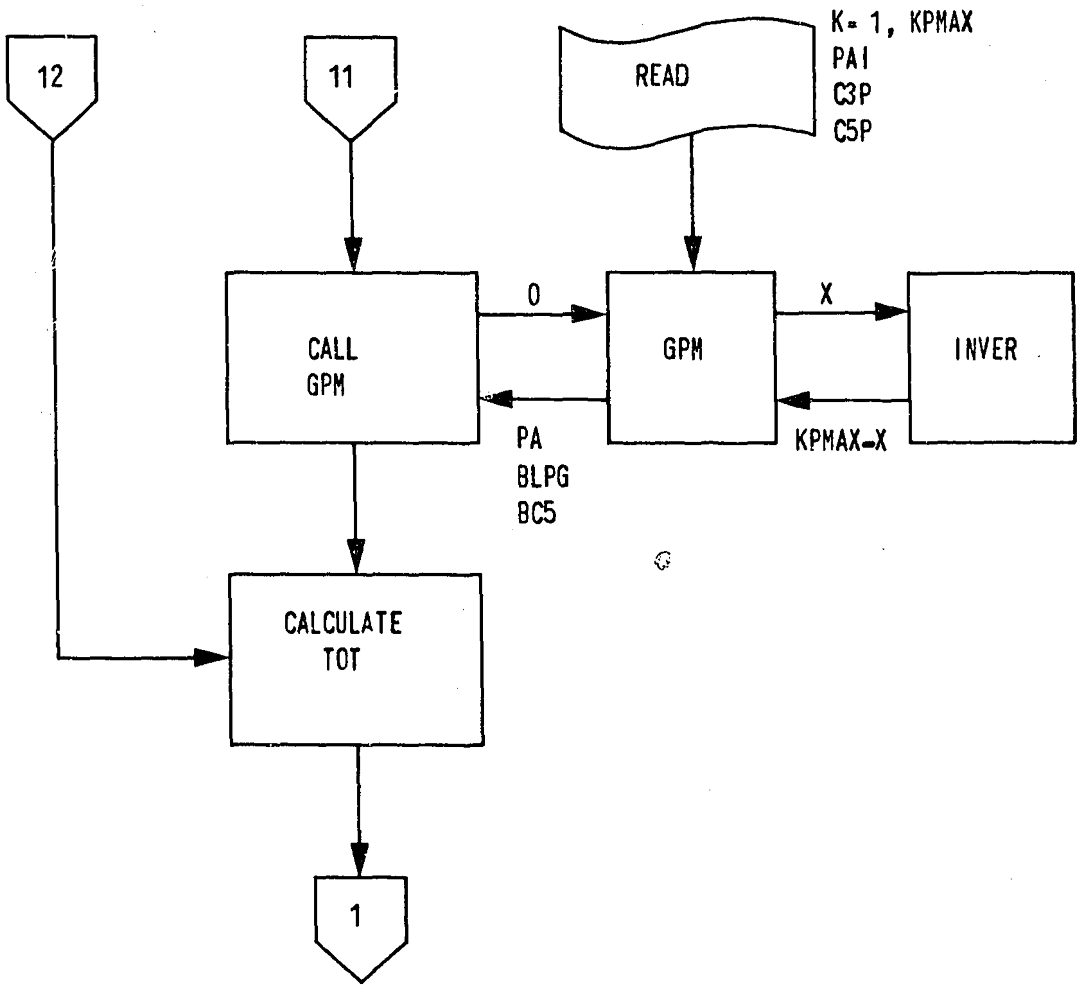
```
1120 FORMAT ( /,10X,"X=",2X,E14.6,5X,"Y=",2X,E14.6,
    1 /,10X,"BLP=",4X,E14.6,10X,"BC0=",4X,E14.6,"BLSCAL=",3X,E14.6,
    2 5X,"BCSCAL=",4X,E14.6)
     CALL PLOT (X,Y,IPEN)
     IPEN=2
     CALL SYMB (X,Y,0.1,2,0.0,-1)
1000 CONTINUE
     IPEN=3
     DO 1100 I=2,NYRMAX
     Y=PB(I)/800.0
     X=-BCO(I)/BCSCAL
     CALL PLOT (X,Y,IPEN)
     IPEN=2
     CALL SYMB(X,Y,0.1,7,0.0,-1)
1100 CONTINUE
     CALL SYMB (-5.0,8.4,0.1,7,0.0,-1)
     CALL SYMB (-4.9,-0.4,0.1,2,0.0,-1)
     CALL SYMB (-6.0,1.0,0.1,IBUF,90.0,64)
     CALL PLOT(0.0,0.0,999)
     CALL GOPLT
     RETURN
     END
     END$
```

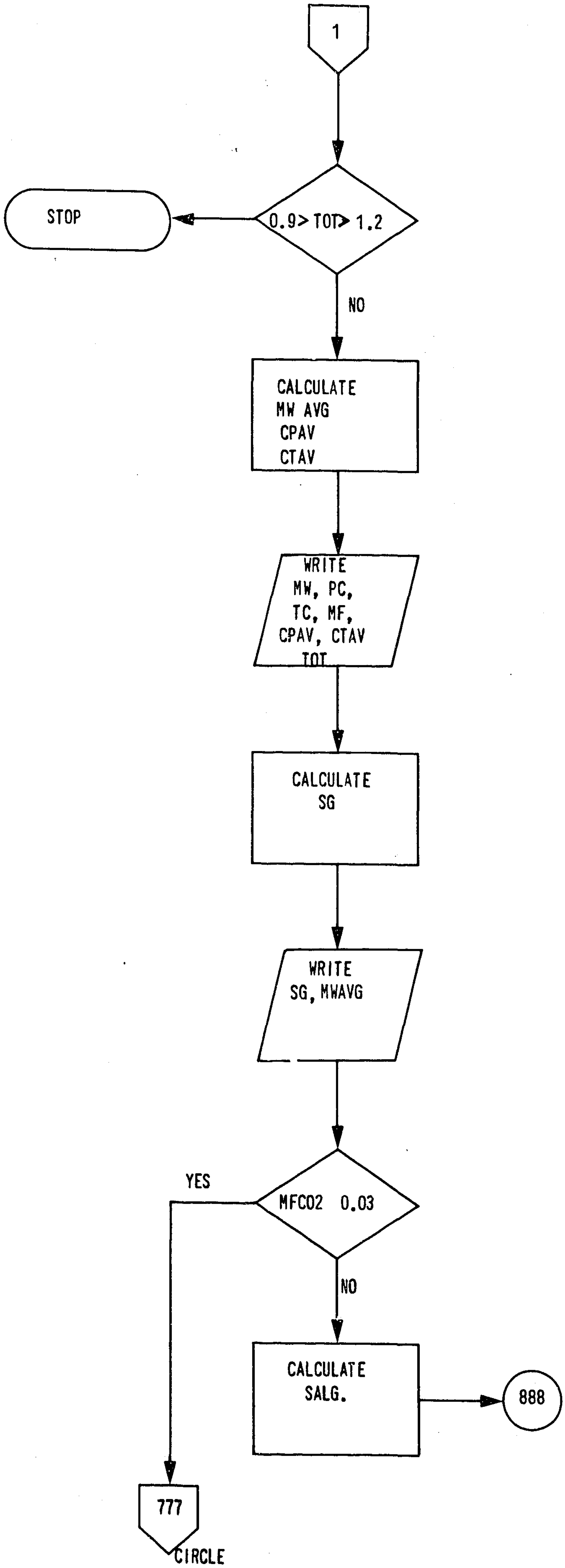
APPENDIX 4A

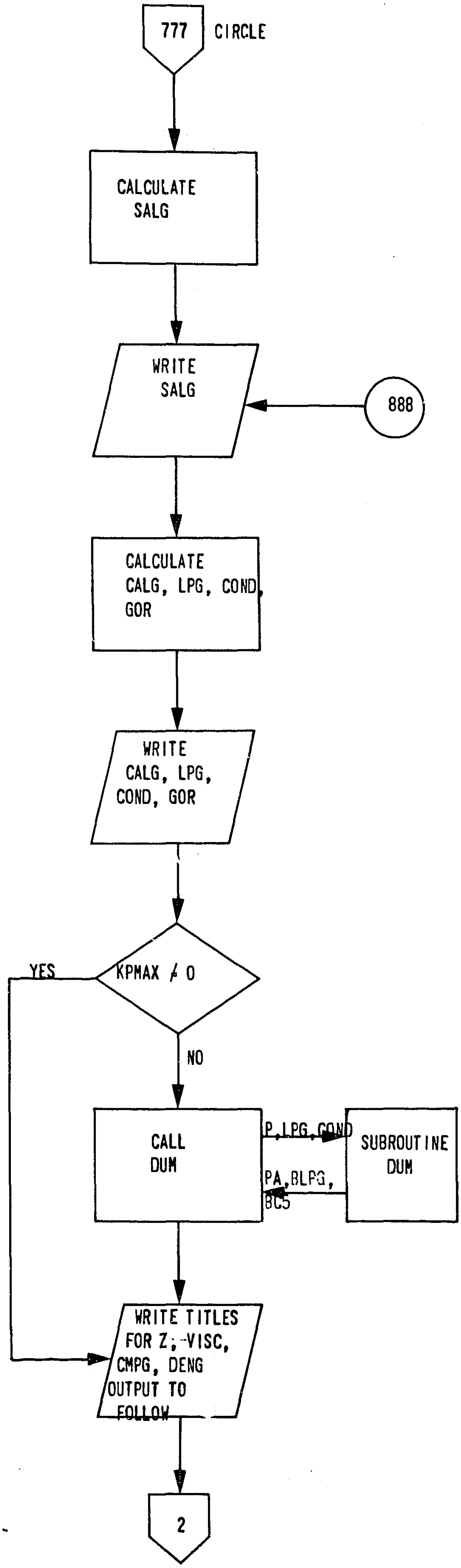
LOGIC FLOW DIAGRAM

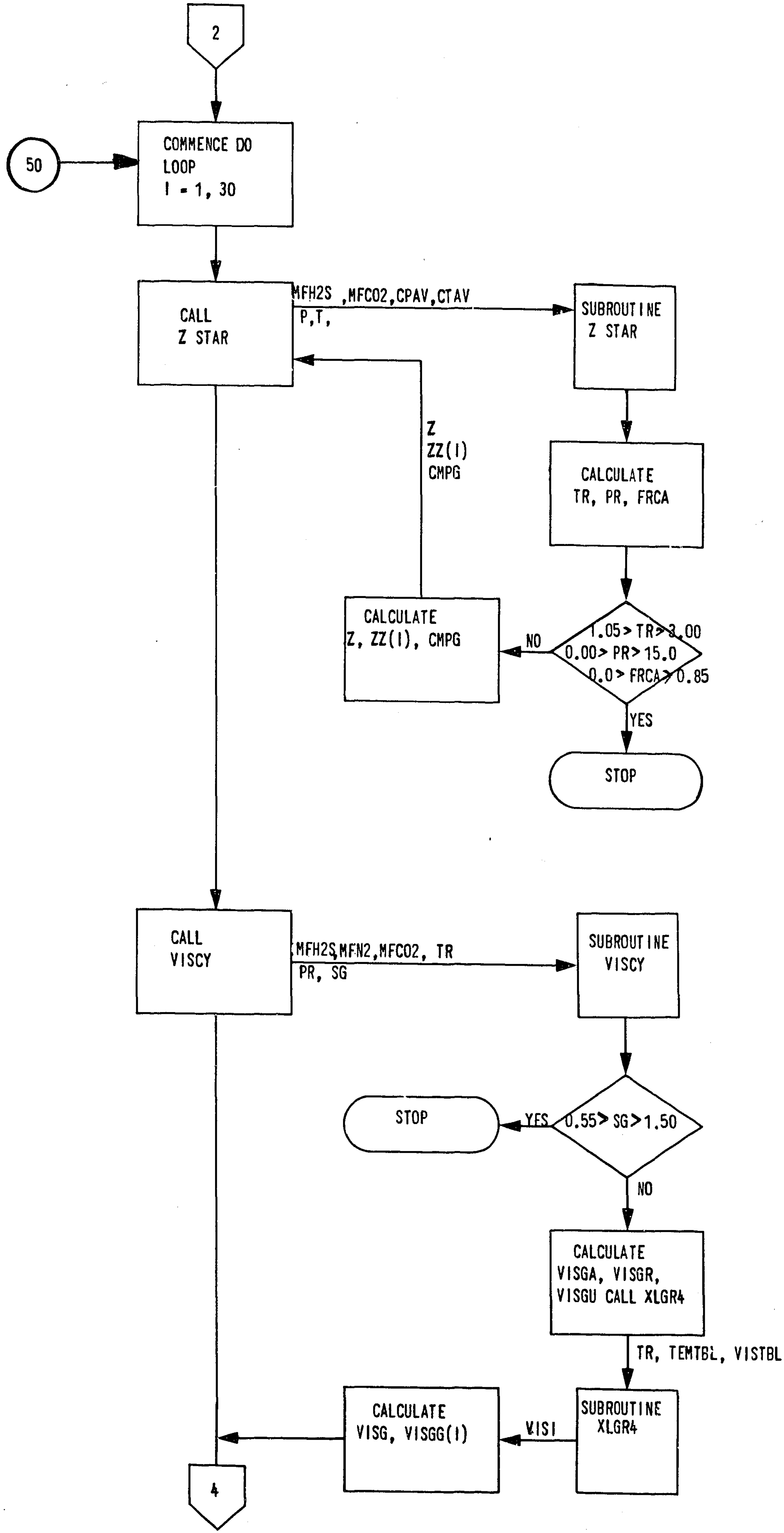
FLOW DIAGRAM OF SEGMENTED PROGRAM GAS 1 : GAS 2 : GAS 3

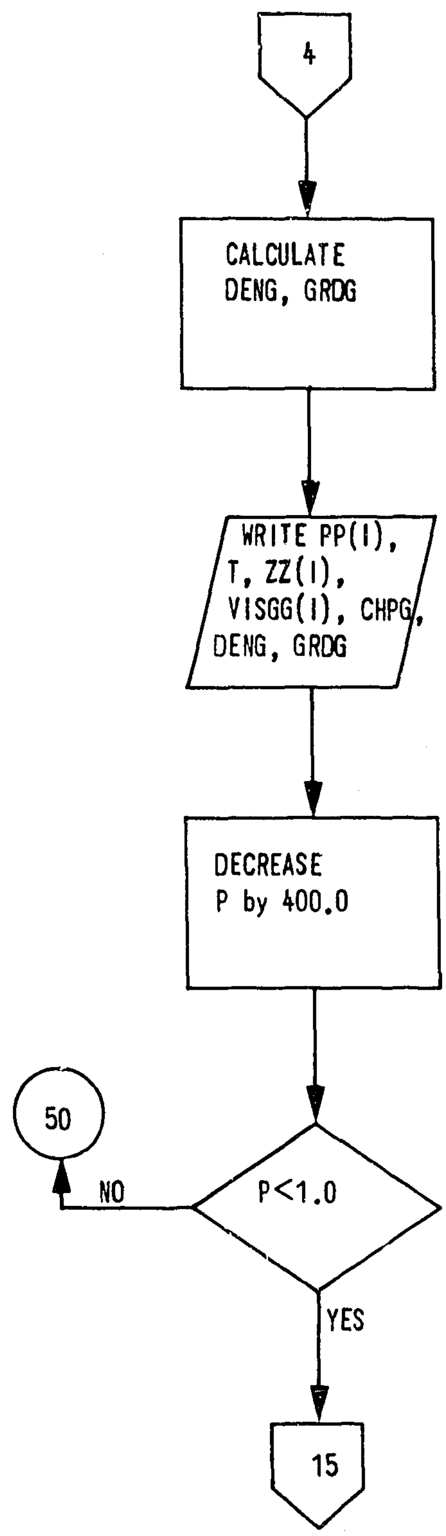


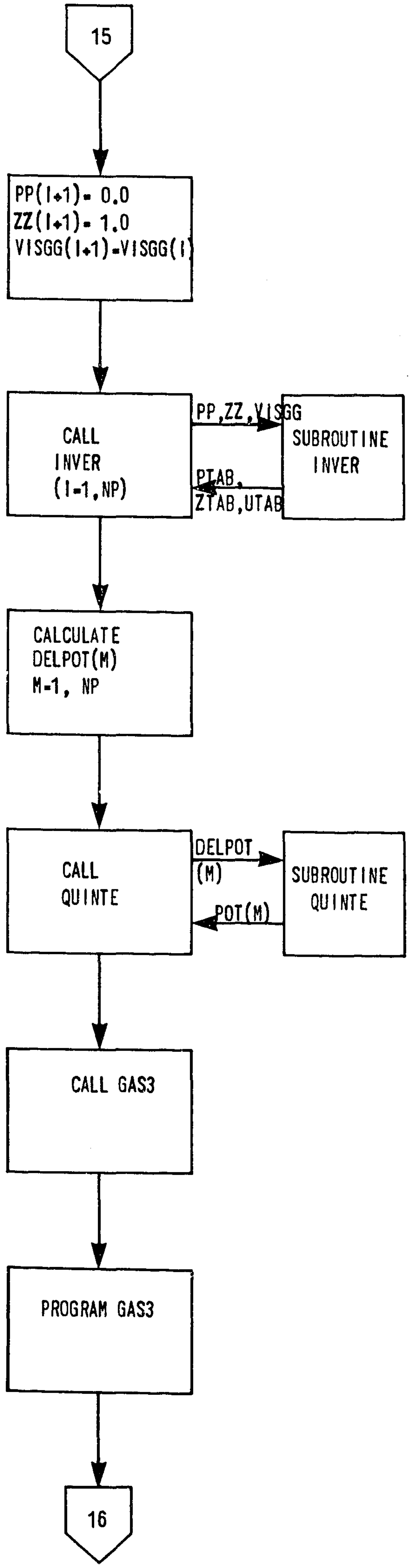

12
11
READ
K= 1, KPMAX
PAI
C3P
C5P
CALL
GPM
0
GPM
X
INVER
PA
BLPG
BC5
KPMAX-X
CALCULATE
TOT
1

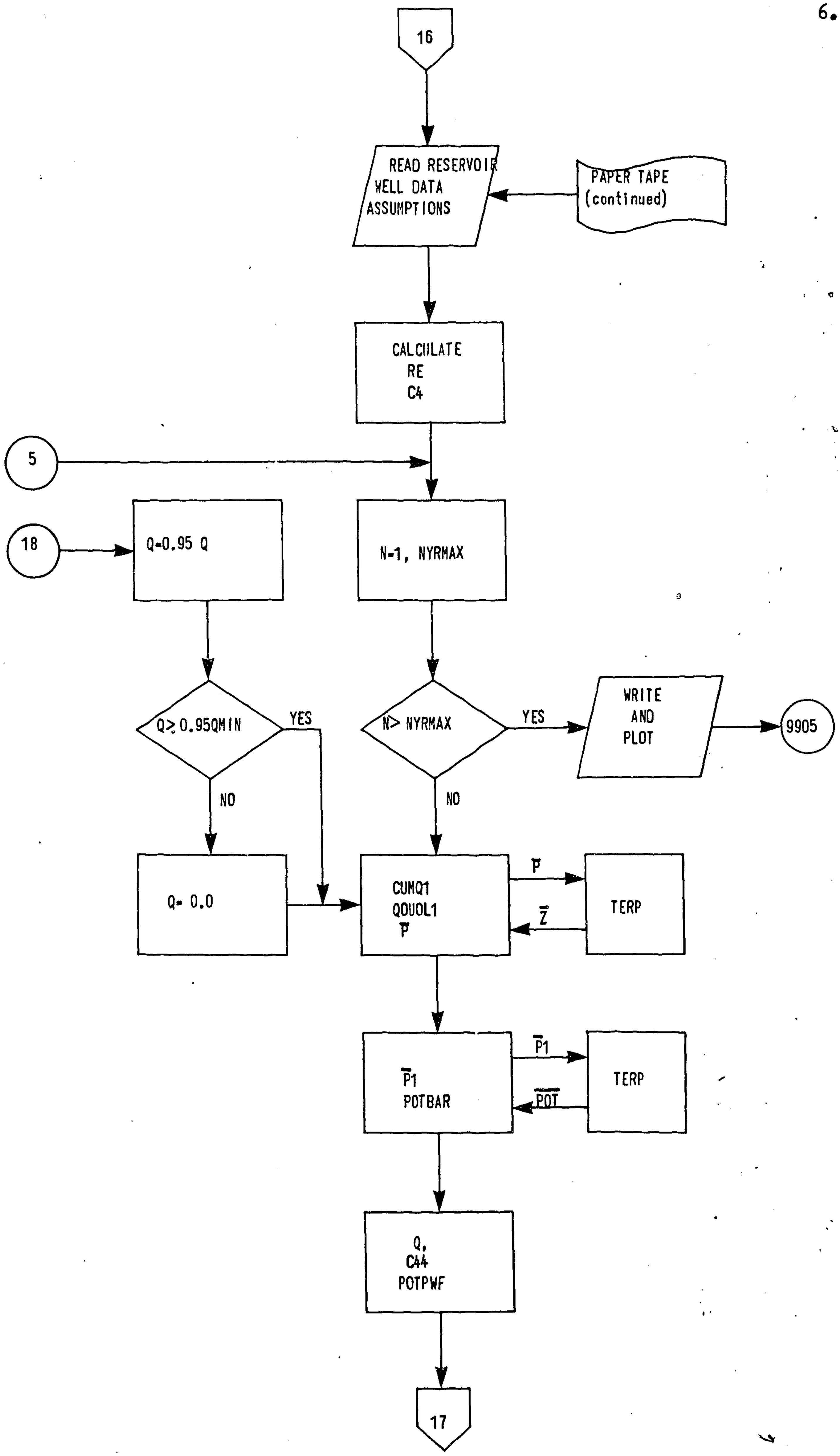

1
STOP
0.9> TOT> 1.2
NO
CALCULATE
MW AVG
CPAV
CTAV
WRITE
MW, PC,
TC, MF,
CPAV, CTAV
TOT
CALCULATE
SG
WRITE
SG, MWAVG
YES
MFCO2 0.03
NO
CALCULATE
SALG.
888
777
CIRCLE

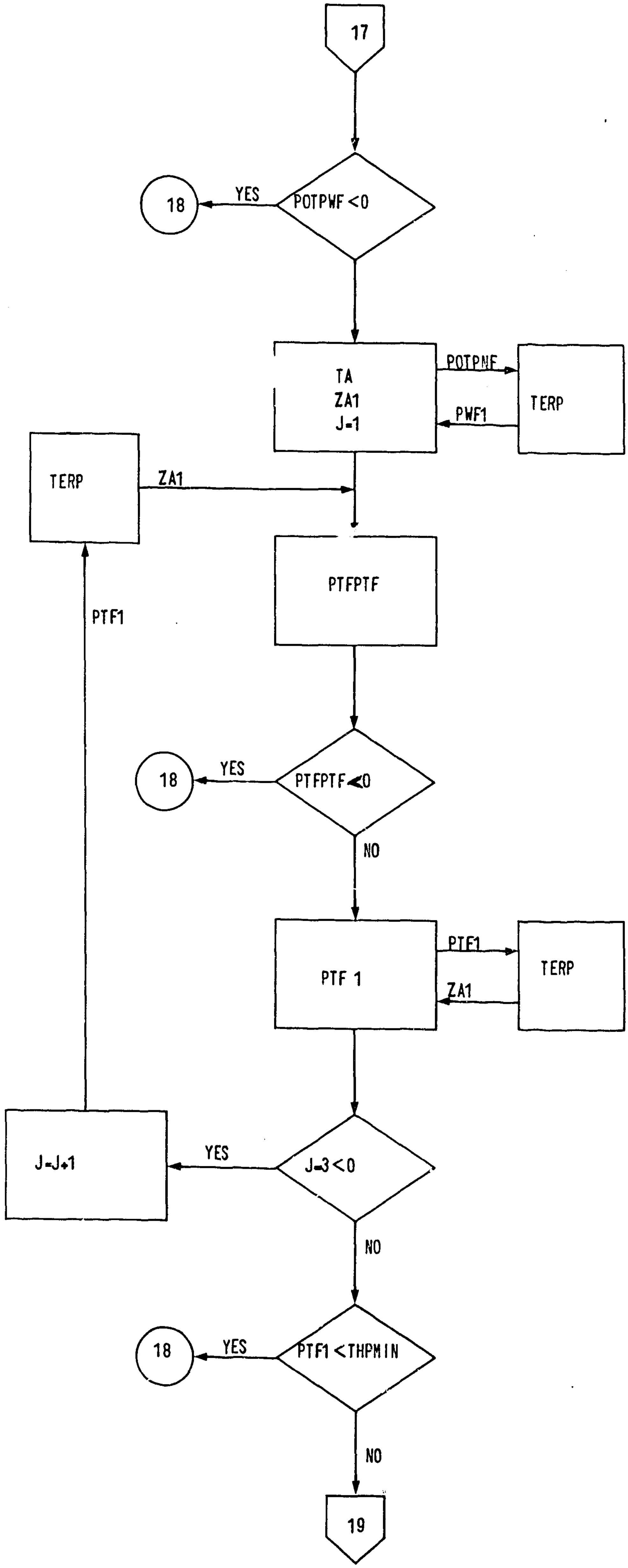

777
CIRCLE
CALCULATE SALG
WRITE SALG
888
CALCULATE CALG, LPG, COND, GOR
WRITE CALG, LPG, COND, GOR
KPMAX ≠ 0
YES
NO
CALL DUM
P, LPG, COND
PA, BLPG, BC5
SUBROUTINE DUM
WRITE TITLES FOR Z, VISC, CMPG, DENG OUTPUT TO FOLLOW
2

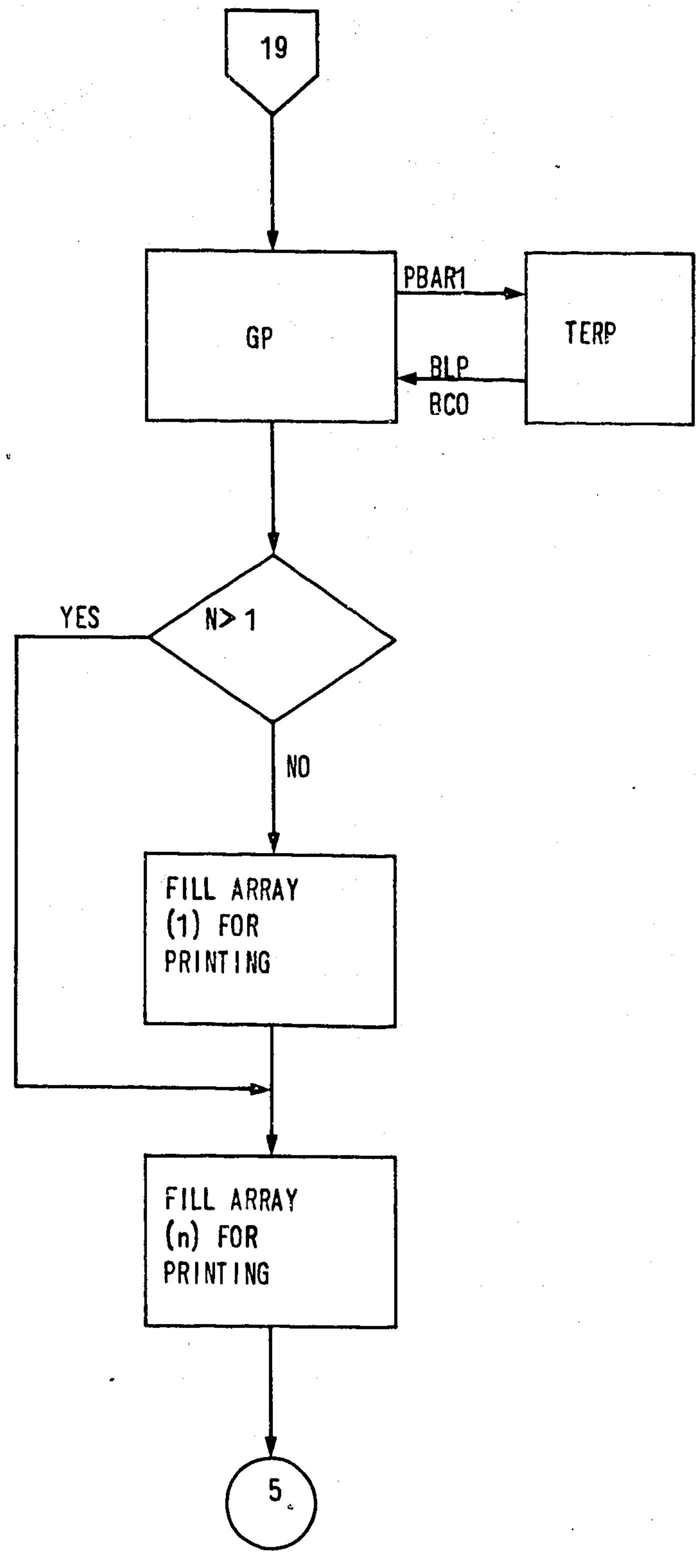

2
50
COMMENCE DO LOOP I = 1, 30
CALL Z STAR
MFH2S ,MFCO2,CPAV,CTAV P,T,
SUBROUTINE Z STAR
CALCULATE TR, PR, FRCA
1.05 > TR > 3.00
0.00 > PR > 15.0
0.0 > FRCA > 0.85
NO
YES
CALCULATE Z, ZZ(I), CMPG
Z
ZZ(I)
CMPG
STOP
CALL VISCY
MFH2S,MFN2,MFCO2, TR PR, SG
SUBROUTINE VISCY
0.55 > SG > 1.50
YES
STOP
NO
CALCULATE VISGA, VISGR, VISGU CALL XLGR4
TR, TEMTBL, VISTBL
SUBROUTINE XLGR4
VISI
CALCULATE VISG, VISGG(I)
4

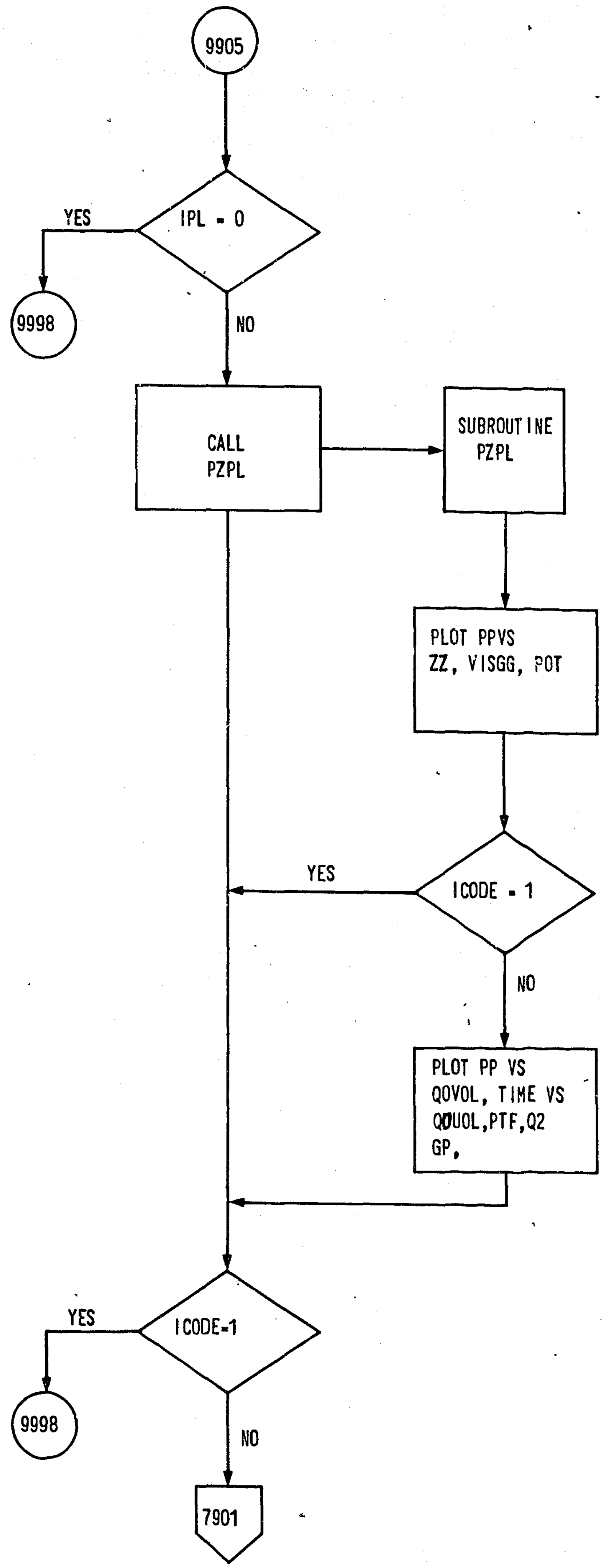

4
CALCULATE
DENG, GRDG
WRITE PP(I),
T, ZZ(I),
VISGG(I), CHPG,
DENG, GRDG
DECREASE
P by 400.0
50
NO
P<1.0
YES
15

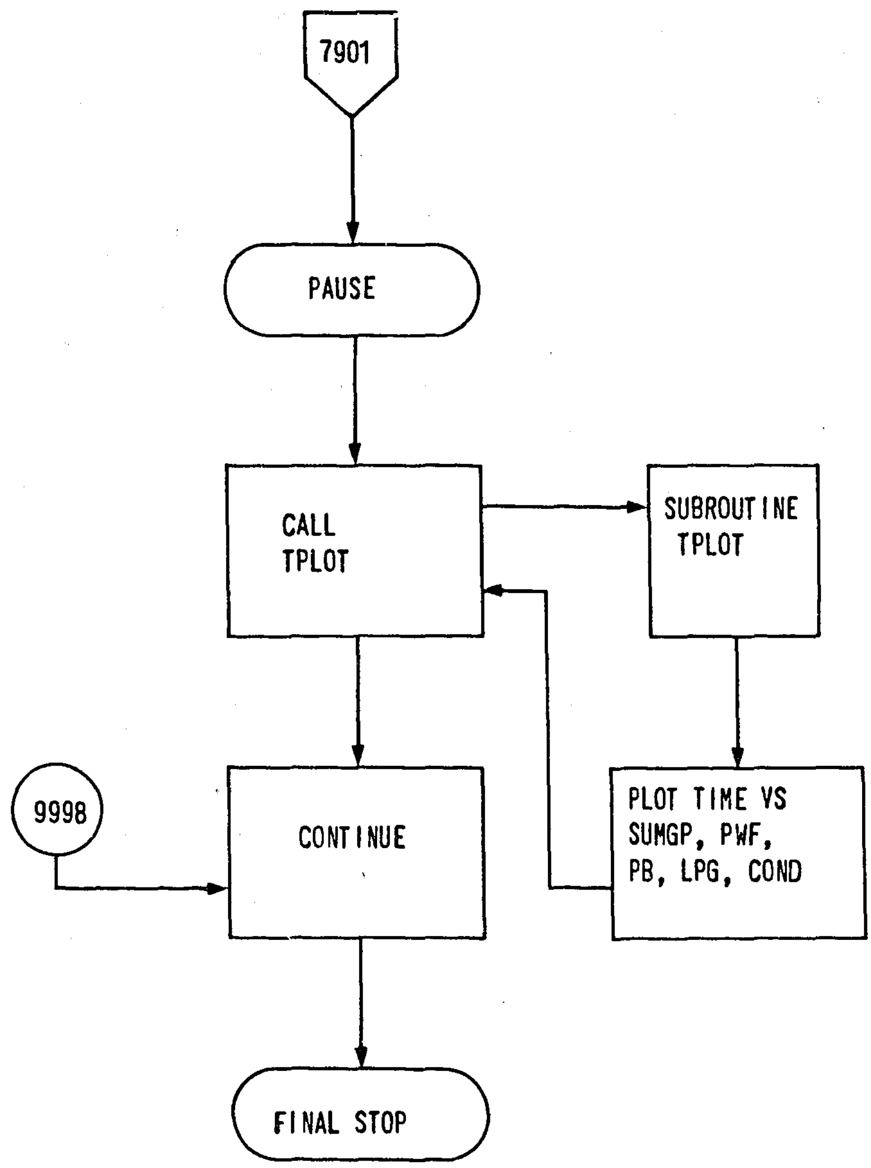

15
PP(I+1)= 0.0
ZZ(I+1)= 1.0
VISGG(I+1)=VISGG(I)
CALL
INVER
(I=1, NP)
PP, ZZ, VISGG
PTAB,
ZTAB, UTAB
SUBROUTINE
INVER
CALCULATE
DELPOT(M)
M=1, NP
CALL
QUINTE
DELPOT
(M)
POT(M)
SUBROUTINE
QUINTE
CALL GAS3
PROGRAM GAS3
16


16
READ RESERVOIR
WELL DATA
ASSUMPTIONS
PAPER TAPE
(continued)
CALCULATE
RE
C4
5
18
Q=0.95 Q
N=1, NYRMAX
Q≥0.95QMIN
YES
NO
N> NYRMAX
YES
NO
WRITE
AND
PLOT
9905
Q= 0.0
CUMQ1
QOUOL1
P̄
P̄
Z̄
TERP
P̄1
POTBAR
P̄1
POT
TERP
Q,
C44
POTPWF
17


17
POTPWF <0
YES
18
TA
ZA1
J=1
POTPNF
PWF1
TERP
TERP
ZA1
PTFPTF
PTF1
PTFPTF <0
YES
18
NO
PTF 1
PTF1
ZA1
TERP
J-J+1
YES
J-3 < 0
NO
PTF1 <THPMIN
YES
18
NO
19


19
GP
PBAR1
TERP
BLP
BCO
N> 1
YES
NO
FILL ARRAY (1) FOR PRINTING
FILL ARRAY (n) FOR PRINTING
5


9905
IPL = 0
YES
9998
NO
CALL
PZPL
SUBROUTINE
PZPL
PLOT PPVS
ZZ, VISGG, POT
YES
ICODE = 1
NO
PLOT PP VS
QOVOL, TIME VS
QOUOL,PTF,Q2
GP,
YES
ICODE=1
9998
NO
7901


7901
PAUSE
CALL
TPLOT
SUBROUTINE
TPLOT
PLOT TIME VS
SUMGP, PWF,
PB, LPG, COND
9998
CONTINUE
FINAL STOP

APPENDIX 4B

DETAILED DELIVERABILITY CALCULATIONS

FLOW CHART

```
      N = 0
C    ******************************************************************
C    *        START CALCULATING ANNUAL PERFORMANCE                     *
C    ******************************************************************
    5 N = N+1
      CUMQ2=CUMQ1
C    ******************************************************************
C    * TEST FOR FINAL YEAR FOR MINIMUM DAILY GROSS GAS PRODUCTION      *
C    *    AND CALCULATE PARAMETERS FOR NEXT YEAR                       *
C    ******************************************************************
      IF(N.GT.NYRMAX) GO TO 9000
      GO TO 118
   18 Q=0.98*Q
      IF(Q.LE.0.98*QMIN) Q=0.0
      IF(CUMQ2.EQ.0.0.AND.Q.EQ.0.0) WRITE(6,117)
  117 FORMAT(/," MINIMUM CUT-OFF RATE IS TOO HIGH")
      IF(CUMQ2.EQ.0.0.AND.Q.EQ.0.0) STOP55
  118 CUMQ1= CUMQ2 + 365.* Q * FLOAT(NW)
      IF(CUMQ1.GT.VOL.AND.N.EQ.1) WRITE(6,119)
  119 FORMAT(" INITIAL PRODUCTION IS AT TOO HIGH A RATE")
      IF(CUMQ1.GT.VOL.AND.N.EQ.1) STOP66
      QOVOL1=CUMQ1 / VOL
      PBAR = ZBAR * PRESSI * (1. - QOVOL1) / ZI
      CALL TERP (ZBAR, PBAR, ZTAB , PTAB,NP,LUN)
      PBAR1= ZBAR * PRESSI * (1. - QOVOL1) / ZI
      WRITE (LUN,310) PBAR1,QOVOL1,Q
  310 FORMAT (3(2X,E13.6))
C     CALCULATION OF GAS FLOW IN RESERVOIR
      CALL TERP (POTBAR, PBAR1,POT, PTAB, NP,LUN)
      Q1 = Q * QOVER
      C44=C4+DTURB*Q1
      C44=((T+460.0)*C44/KH/0.7)*1000000.0
      WRITE(LUN,302) RE,DTURB,C44
  302 FORMAT (20X,"RE=",E14.6,20X,"DTURB=",E14.6,20X,"C44=",E14.6)
      POTPWF = (POTBAR - (C44* Q1))
      IF(POTPWF.LE.0.0)GO TO 18
      CALL TERP (PWF1,POTPWF, PTAB, POT, NP,LUN)
C     CALCULATION OF FLOW IN TUBING
C     R.V.SMITH MODIFIED WEYMOUTH EQUATION,"HANDBOOK OF NATURAL GAS
C     ENGINEERING" BY KATZ ET. AL.(1959,P 309)
      TA = (T + TEMTOP)/2.0 + 460.
      ZA1= 0.90
      J = 1
   19 S1 = 0.0375 * SG * TBGEL / TA / ZA1
      A1 = (TBGDIA)** 5.0 / SG / TA / ZA1 / FR / TBGEL / FAC
      E1 = EXP (S1)
      PTFPTF= (((1.-E1)/S1 * 25.0 / A1)* Q1* Q1+  PWF1* PWF1)
     A   /E1
      IF(PTFPTF.LT.0.0) GO TO 18
      PTF1=SQRT(PTFPTF)
      WRITE (LUN,304) ZA1,S1,A1,E1,PTF1
  304 FORMAT (2X,5(E13.6))
      IF(J-3) 11,12,12
   11 J = J + 1
```

A B C D E

```
      CALL TERP (ZA1, PTF1,ZTAB, PTAB, NP,LUN)
      GO TO 19
   12 CONTINUE
      IF((PTF1- THPMIN).LT.0.0) GO TO 18
C    ****************************************************************************
C    * FILL ARRAYS FOR YEAR N AND GO TO NEXT N                                 *
C    ****************************************************************************
   90 Q2 (N) = Q
      GP1(N) = Q * 365. * FLOAT(NW)/1000.
      IF(PA(KPMAX)-PRESSI) 142,143,143
  142 WRITE (6,144)PA(KPMAX),PRESSI
  144 FORMAT (15X,"PA(KPMAX) = ",E14.6,15X,"PRESSI = "E14.6)
      PA(KPMAX)=PRESSI
  143 CALL TERP (BLP(N),PBAR1,BLPG,PA,KPMAX,LUN)
      CALL TERP (BCO(N),PBAR1,BC5,PA,KPMAX,LUN)
      GP(N)=GP1(N)*SALG
      IF(N.GT.1)GO TO 43
      SUMGP(1)= GP(1)
      GPLPG(1)=BLP(1)*GP1(1)
      GPCON(1)=BCO(1)*GP1(1)
      SUMLPG(1)=GPLPG(1)/1000.0
      SUMCON(1)= BCO(1)*GP1(1)/1000.0
      GO TO 42
43    GPLPG(N)=BLP(N)*GP1(N)
      GPCON(N)=BCO(N)*GP1(N)
      SUMGP(N)=SUMGP(N-1)+GP(N)
      SUMLPG(N)=SUMLPG(N-1)+GPLPG(N)/1000.0
      SUMCON(N)=SUMCON(N-1)+GPCON(N)/1000.0
      IF(Q2(N).LE.0.0) GPLPG(N)=0.0
      IF(Q2(N).LE.0.0) GPCON(N)=0.0
42    QOVOL (N) = QOVOL1
      PTF (N)   = PTF1
      PWF (N)   = PWF1
      PB(N)  = PBAR1
      GO TO 5
9000  WRITE(6,81)(TITLE(J),J=1,26)
*EOF
```