UNIVERSITI
TEKNOLOGI
PETRONAS

# FINAL EXAMINATION
# MAY 2024 SEMESTER

| | | |
|---|---|---|
| **COURSE** | : | **PEB1053/PFB1053 - RESERVOIR FLUID PROPERTIES** |
| **DATE** | : | **9 AUGUST 2024 (FRIDAY)** |
| **TIME** | : | **9:00 AM - 12:00 NOON (3 HOURS)** |

## INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions in the Answer Booklet.
2. Begin **EACH** answer on a new page in the Answer Booklet.
3. Indicate clearly answers that are cancelled, if any.
4. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions, if any.
5. **DO NOT** open this Question Booklet until instructed.

**Note** :

i. There are **TWELVE (12)** pages in this Question Booklet including the cover page and the Appendix.

ii. **DOUBLE-SIDED** Question Booklet.

1. a. Describe the differences between the pressure-volume (P-V) diagrams of pure systems and binary systems.

[8 marks]

b. i. Sketch a retrograde gas (condensate) phase diagram by indicating the following key features in your sketch:

- Bubble point and dew point lines
- Critical point
- Isovol lines of constant proportion of gas-liquid
- Line of isothermal reduction at reservoir condition
- Region of retrograde condensate.

[8 marks]

ii. Describe the liquid drop-out phenomenon in retrograde gas (condensate) reservoir and discuss the mitigation plans to prevent this issue.

[8 marks]

2. a. With the help of a sketch, illustrate the relationship between gas viscosity and pressure. Explain the effects of temperature on gas viscosity under various pressure conditions.

[12 marks]

b. A well produces natural gas with a specific gravity of 0.825 at reservoir conditions of 3200 psia and 180°F.

i. Determine the value of gas compressibility factor at reservoir conditions of 3200 psia and 180°F.

[8 marks]

ii. Calculate the viscosity of the natural gas at reservoir conditions.

[6 marks]

3. a. With the aid of a diagram, discuss the relationship between the total formation volume factor and pressure. In your answer, indicate the relationships between the total formation volume factor, the oil and gas formation volume factors, and the solution gas-oil ratio.

[12 marks]

b. **TABLE Q3** shows the composition of a hydrocarbon liquid from Well S9.

**TABLE Q3** : Hydrocarbon liquid composition.

| Component | Composition (Mole fraction) |
|---|---|
| Propane | 0.025 |
| *i*-Butane | 0.325 |
| *n*-Pentane | 0.650 |

i. Calculate pseudoliquid density at 14.7 psia and 60°F.

[8 marks]

ii. Calculate the density of a reservoir liquid at reservoir conditions of 4000 psia and 100°F.

[6 marks]

4. a. Describe the procedures of flash vaporization test, differential vaporization test, and separator test carried out in routine pressure-volume-temperature (PVT) testing.

[15 marks]

b. **TABLE Q4** shows the separator test data for a reservoir oil sample from Zeta Field. The volume of separator liquid was determined at separator pressure and temperature of 110 psig and 70°F before it was discharged into the stock tank. Note: 1 cc = $6.27 \times 10^{-6}$ bbl.

**TABLE Q4** : Separator test data.

| Parameter | Value |
|---|---|
| Volume of oil at bubble point pressure ($P_b$) and reservoir temperature ($T_{res}$) | 184.20 cc |
| Volume of separator liquid in the cell at 110 psig and 70°F | 145.50 cc |
| Volume of stock-tank oil at at 0 psig and 70°F | 136.50 cc |
| Volume of stock-tank oil at 0 psig and 60 °F | 125.60 cc |
| Volume of gas removed from separator | 0.645 scf |
| Volume of gas removed from stock tank | 0.095 scf |

i. Determine the gas-oil ratio at separator and stock-tank at standard conditions.

[6 marks]

ii. Calculate the oil formation volume factor at bubble point ($B_{oSb}$).

[3 marks]

- END OF PAPER -

**APPENDIX**

**Conversion Factors**

1 STB = 5.615 cu ft

1 scf = 28316.85 cc

1 cc = $6.27 \times 10^{-6}$ bbl

**Additional information**

Apparent molecular weight of air = 28.97 lb/lb-mole

Density of water = 62.37 lb/cu ft

**Formulas**

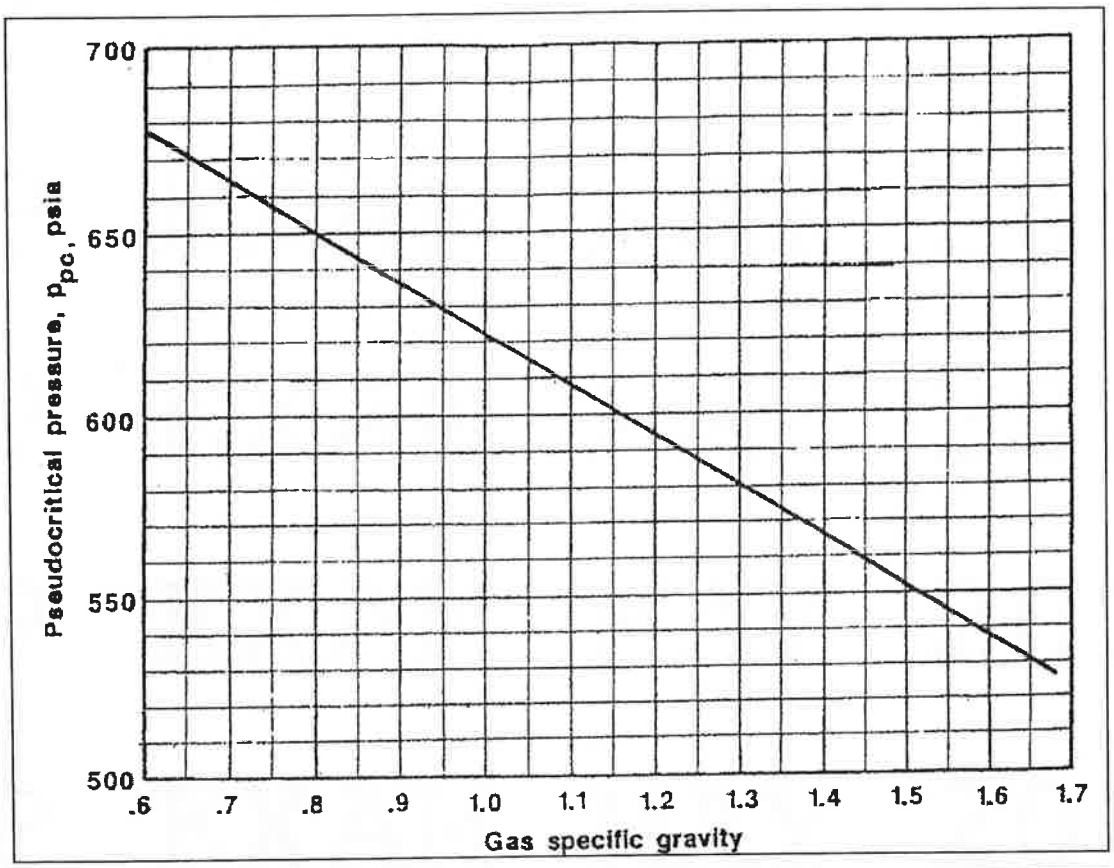
$$\gamma_g = \frac{M_g}{M_{air}}$$

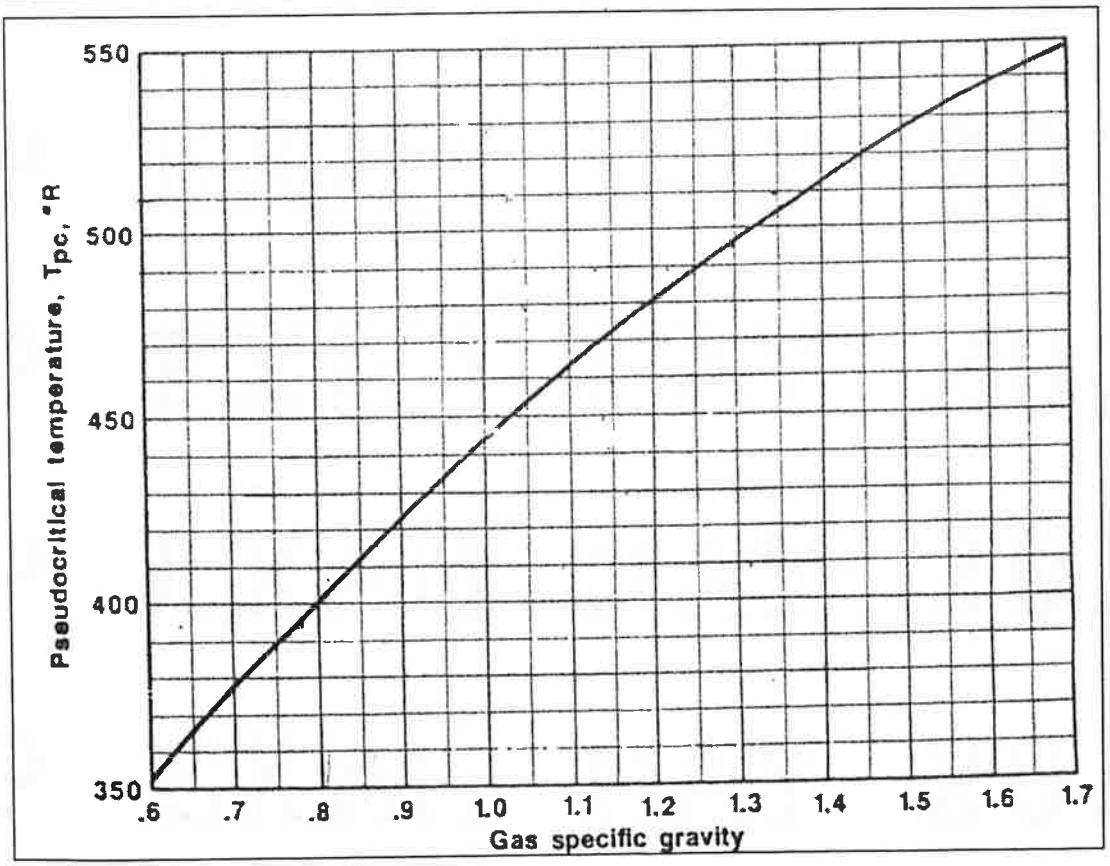
$$\mu_{ratio} = \frac{\mu_g}{\mu_{atm}}$$

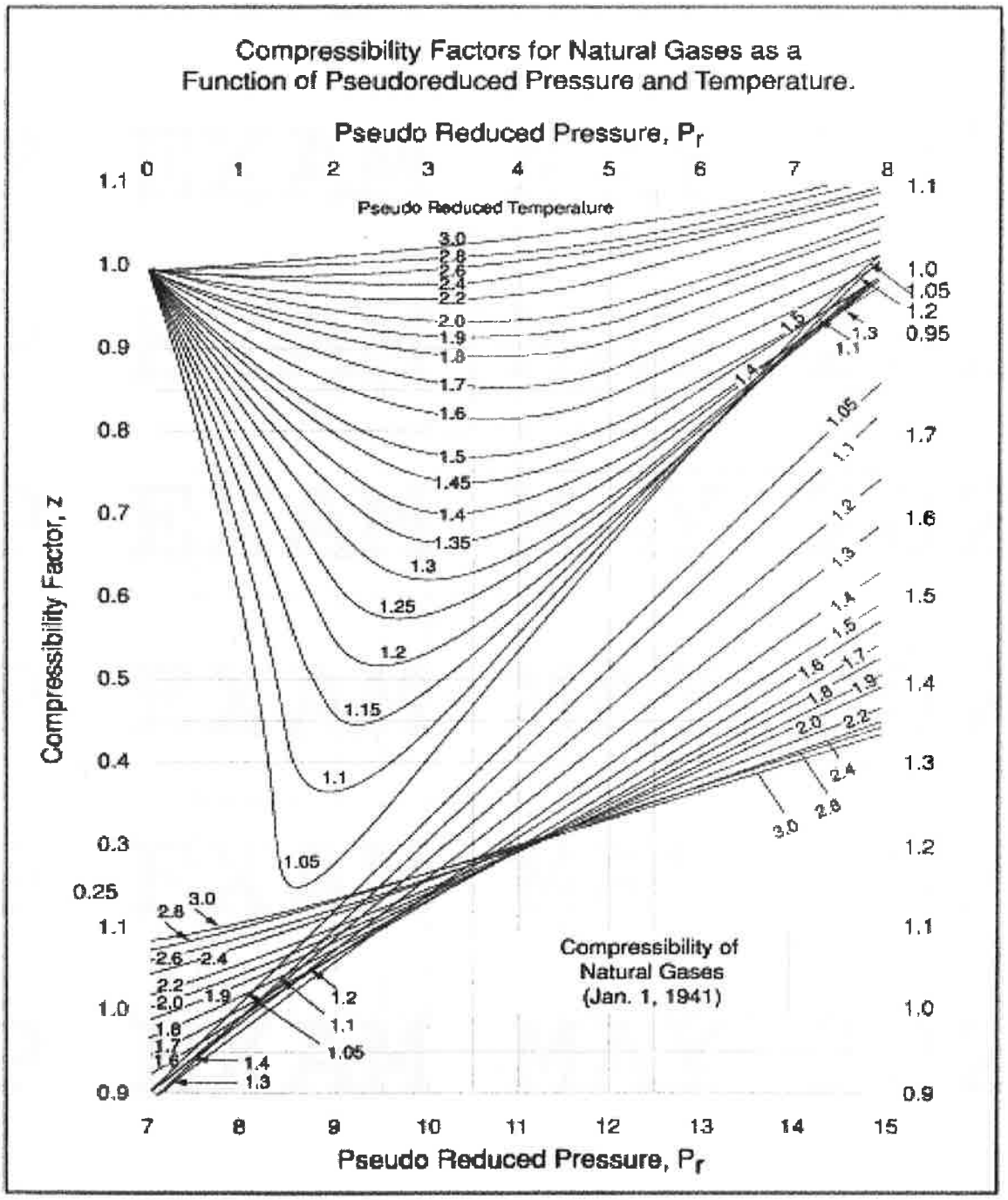
$$B_t = B_o + B_g(R_{sb} - R_{sD})$$

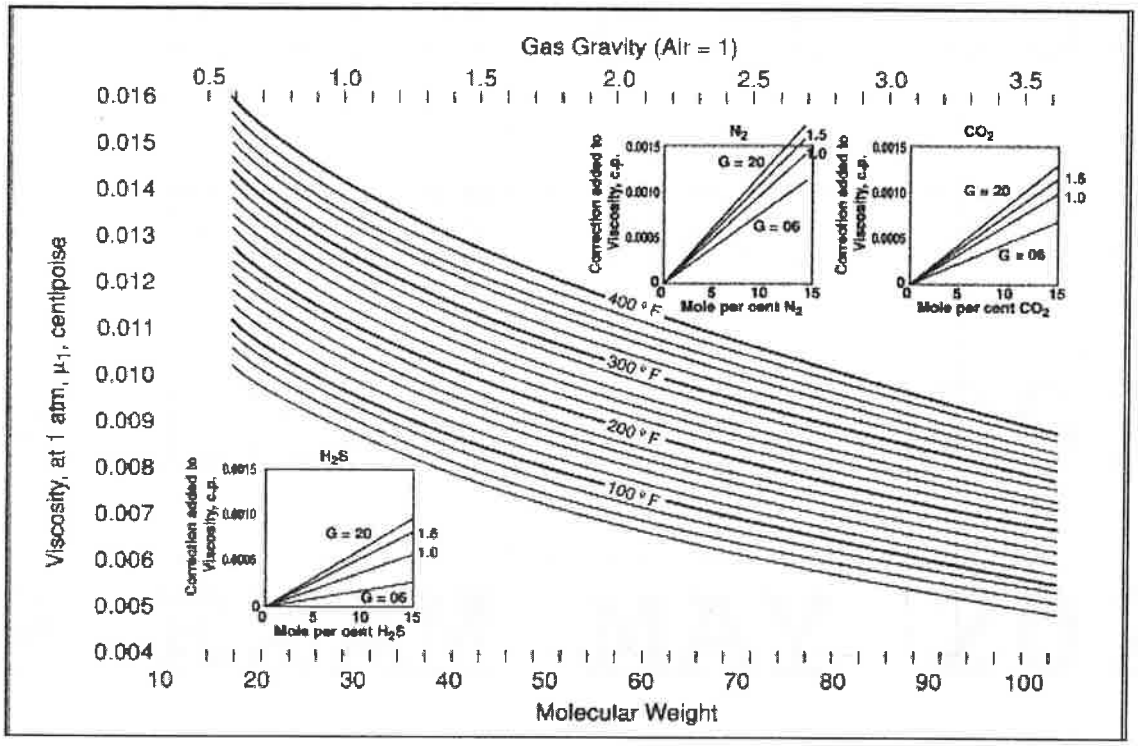
## PHYSICAL PROPERTIES OF THE PARAFFIN HYDROCARBONS & MISCELLANEOUS COMPOUNDS

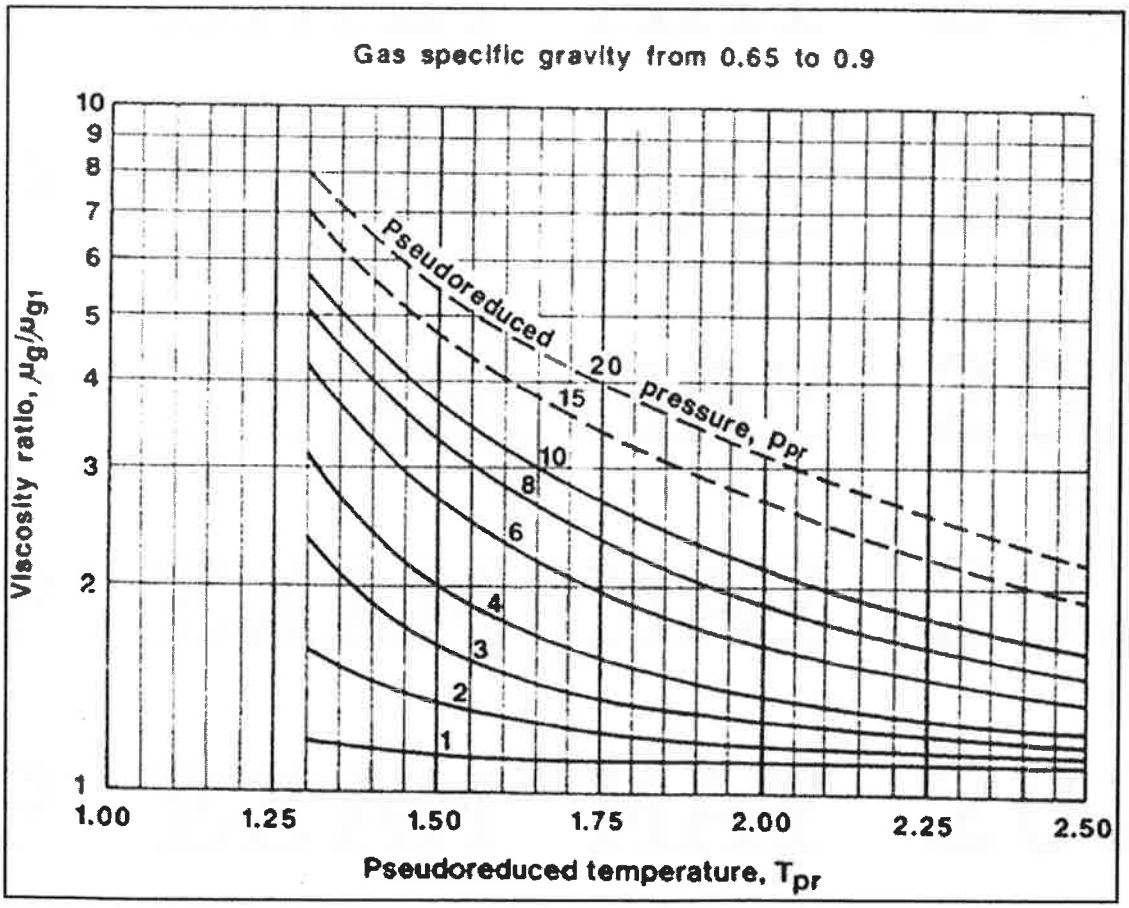
| COMPOUND | MOLECULAR WEIGHT | BOILING POINT AT 14.7 PSIA °F | CRITICAL CONSTANTS | | LIQUID DENSITY 60°F, 14.7 PSIA | | GAS DENSITY 60°F, 14.7 PSIA (PERFECT GAS) | | CU FT GAS PER GALLON LIQUID (ACTUAL |
|---|---|---|---|---|---|---|---|---|---|
| | | | PRESSURE PSIA | TEMPERATURE °R | Gm PER cc | POUNDS PER CU FT | POUNDS PER MCF | CU FT GAS PER GALLON LIQUID | |
| METHANE | 16.04 | -258.7 | 673 | 344 | - | - | 42.27 | - | - |
| ETHANE | 30.07 | -127.5 | 709 | 550 | - | - | 79.23 | - | - |
| PROPANE | 44.09 | -43.7 | 618 | 666 | 0.5072 | 31.66 | 116.19 | 36.35 | 35.78 |
| ISO-BUTANE | 58.12 | 10.9 | 530 | 733 | 0.5625 | 35.12 | 153.15 | 30.59 | 29.70 |
| N-BUTANE | 58.12 | 31.1 | 551 | 766 | 0.5836 | 36.43 | 153.15 | 31.75 | 30.77 |
| ISO-PENTANE | 72.15 | 82.1 | 482 | 830 | 0.6241 | 38.96 | 190.11 | 27.35 | 26.17 |
| N-PENTANE | 72.15 | 96.9 | 485 | 847 | 0.6305 | 39.36 | 190.11 | 27.63 | 26.36 |
| N-HEXANE | 86.17 | 155.7 | 434 | 915 | 0.6637 | 41.43 | 227.07 | 24.34 | 22.83 |
| N-HEPTANE | 100.2 | 209.2 | 397 | 973 | 0.6875 | 42.92 | 264.03 | 21.69 | 19.95 |
| N-OCTANE | 114.2 | 258.2 | 370 | 1025 | 0.7062 | 44.09 | 300.99 | 19.55 | 17.77 |
| N-NONANE | 128.3 | 303.4 | 335 | 1073 | 0.7211 | 45.02 | 337.95 | 17.78 | 15.88 |
| N-DECANE | 142.3 | 345.2 | 312 | 1115 | 0.7333 | 44.78 | 374.91 | 16.30 | 14.30 |
| AIR | 28.97 | -317.7 | 547 | 239 | | | | | |
| NITROGEN | 28.02 | -320.4 | 492 | 227 | - | - | | | |
| OXYGEN | 32.00 | -297.4 | 732 | 278 | - | - | | | |
| CARBON DIOXIDE | 44.01 | -109.3 | 1072 | 548 | - | - | | | |
| HYDROGEN SULPHIDE | 34.08 | -76.5 | 1306 | 673 | | | | | |
| WATER | 18.02 | 212.0 | 3206 | 1165 | 0.9991 | 62.37 | | | |

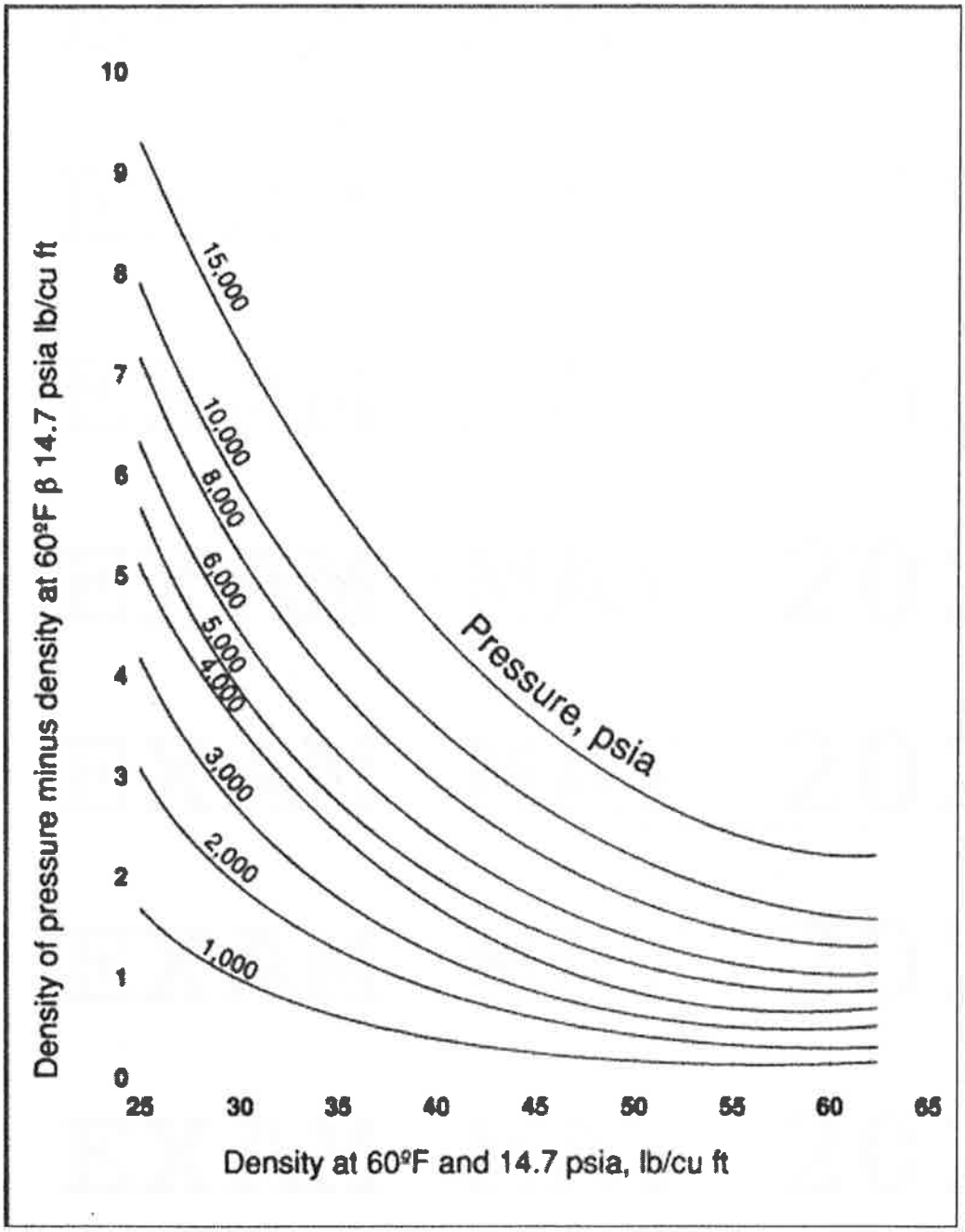

Pseudocritical pressure, $p_{pc}$, psia
700
650
600
550
500
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
Gas specific gravity

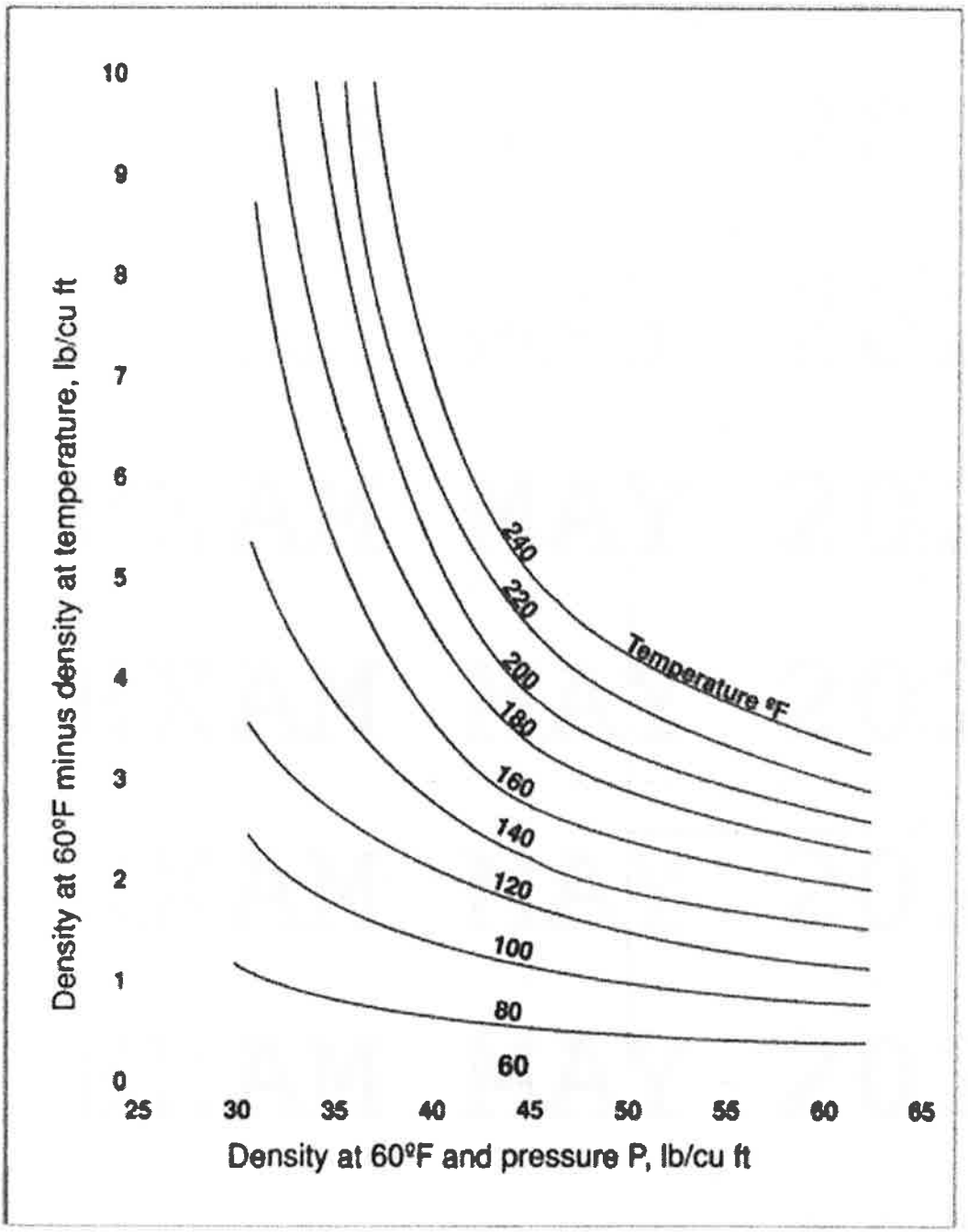

Pseudocritical temperature, $T_{pc}$, °R
550
500
450
400
350
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
Gas specific gravity


Compressibility Factors for Natural Gases as a Function of Pseudoreduced Pressure and Temperature.
Pseudo Reduced Pressure, $P_r$
Pseudo Reduced Temperature
Compressibility Factor, z
Compressibility of Natural Gases (Jan. 1, 1941)
Pseudo Reduced Pressure, $P_r$


Gas Gravity (Air = 1)
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Viscosity, at 1 atm, $\mu_1$, centipoise
0.016
0.015
0.014
0.013
0.012
0.011
0.010
0.009
0.008
0.007
0.006
0.005
0.004
400 °F
300 °F
200 °F
100 °F
$N_2$
$CO_2$
$H_2S$
G = 20
G = 06
1.5
1.0
Correction added to Viscosity, c.p.
Mole per cent $N_2$
Mole per cent $CO_2$
Mole per cent $H_2S$
10
20
30
40
50
60
70
80
90
100
Molecular Weight


Gas specific gravity from 0.65 to 0.9
Viscosity ratio, $\mu_g/\mu_{g1}$
10
9
8
7
6
5
4
3
2
1
Pseudoreduced pressure, $p_{pr}$
20
15
10
8
6
4
3
2
1
1.00
1.25
1.50
1.75
2.00
2.25
2.50
Pseudoreduced temperature, $T_{pr}$


Density of pressure minus density at 60°F β 14.7 psia lb/cu ft
10
9
8
7
6
5
4
3
2
1
0
15,000
10,000
8,000
6,000
5,000
4,000
3,000
2,000
1,000
Pressure, psia
25
30
35
40
45
50
55
60
65
Density at 60°F and 14.7 psia, lb/cu ft


Density at 60°F minus density at temperature, lb/cu ft
10
9
8
7
6
5
4
3
2
1
0
240
220
200
180
160
140
120
100
80
60
Temperature °F
25
30
35
40
45
50
55
60
65
Density at 60°F and pressure P, lb/cu ft