National Exams December 2014

98-Pet-B2, Natural Gas Engineering

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. This is a CLOSED BOOK exam.
3. **Only A Casio or Sharp approved calculator models are permitted.**
4. FIVE (5) questions constitute a complete exam paper.
5. The first five questions as they appear in the answer book will be marked.
6. All questions are of equal value unless otherwise stated and all parts in a multipart question have equal weight.
7. Clarity and organization of your answers are important, clearly explain your logic.
8. Pay close attention to units, some questions involve oilfield units, and these should be answered in the field units. Questions that are set in other units should be answered in the corresponding units.
9. A formula sheet is provided at the end of questions

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Question 1 (20 Marks)
Explain (briefly in one or two sentences) the following concepts.

a) Retrograde condensation
b) Dew point pressure
c) Critical point
d) Circondentherm
e) Wet gas
f) Pseudopressure
g) Absolute open flow (AOF)
h) Accuracy of a flow meter
i) Liquid drop out
j) Repeatability (precision) of a flow meter

Question 2 (20 Marks)
A gas well is producing a natural gas with the following composition:

Component	Mole Fraction	Molecular Weight (lb_{mass}/lb_{mole})
CO_2	0.04	44.01
H_2S	0.03	34.08
N_2	0.01	28.01
Methane	0.75	16.04
Ethane	0.12	30.07
Propane	0.05	44.11

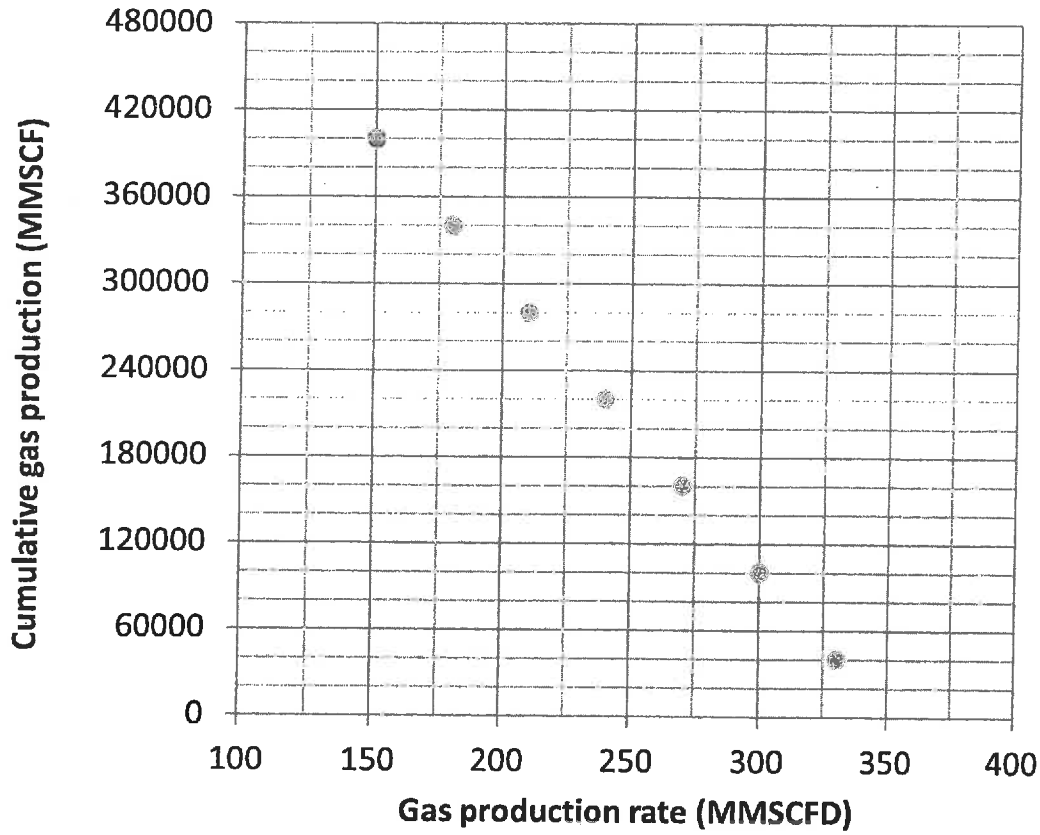
Calculate the apparent molecular weight, specific gravity, real gas density (in lb_{mass}/ft^3) and gas formation volume factor (in ft^3/SCF) at 3650 psia and 210 °F.

Question 3 (20 Marks)
A 48-inch 20 km long gas pipeline transports a natural gas with a specific gravity of 0.7 from a Station A at 2500 kPa to Station B at 1500 kPa. Calculate the pipeline flow capacity and gas velocity inside the pipeline using the given data.

Pipeline wall roughness, ε	5.85×10^{-4} m
Base temperature, T_{sc}	288 K
Base pressure, p_{sc}	101.325 kPa
Gas average temperature, $\overline{T}$	290 K
Gas viscosity, μ	0.015 cp
Gas average deviation factor, $\overline{Z}$	0.85

Question 4 (20 Marks)
Cumulative gas production versus production rate available from a volumetric dry gas field with the boundary-dominated flow condition is given in the following.

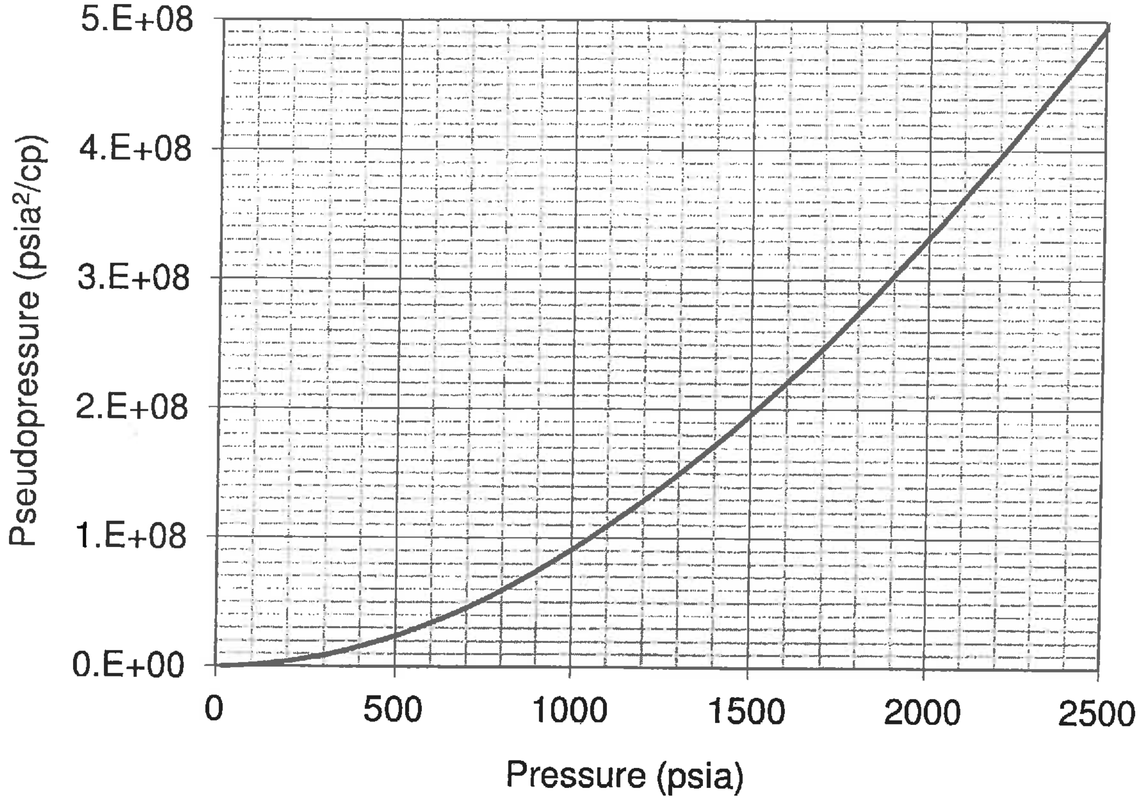
a) Calculate the cumulative gas produced after 10 years of production.
b) Calculate gas reserves if an economic limit of 25 MMSCFD is allowed.



Question 5 (20 Marks)

A gas well in an infinite reservoir was produced at constant rate of 7 MMSCFD. Use the real gas pseudo pressure versus pressure plot and the following data to find well pressure after 36 hr of production using the real gas pseudo pressure method.

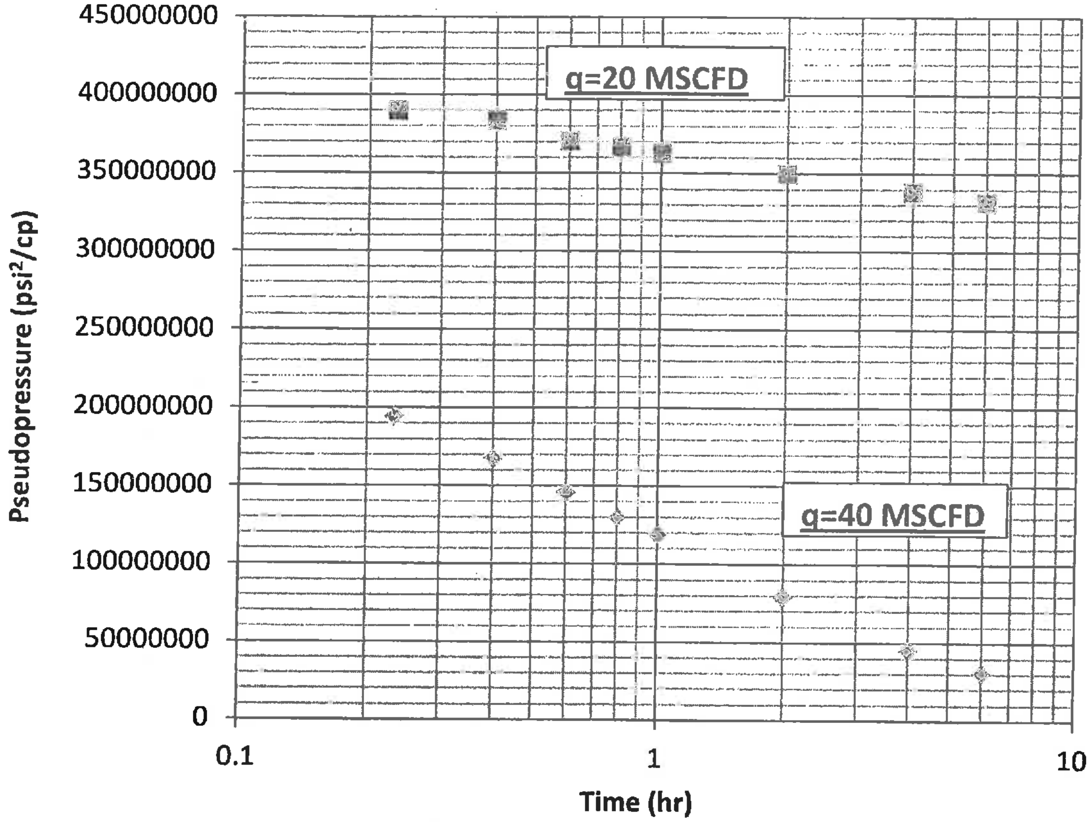
Initial pressure, p_i	2000 psia
Reservoir Temperature, T	580°R
Formation thickness, h	39 ft
Porosity, ϕ	0.15
Permeability, k	20 mD
Well radius, r_w	0.4 ft
Gas isothermal compressibility, c_i	0.00053 psi^{-1}



Question 6 (20 Marks)

Two drawdown tests were conducted on a gas well producing from a dry gas reservoir at 20000 and 40000 MSCFD. Use the real gas pseudo pressure semi-log plots and the following reservoir data to estimate the true skin factor and the non-Darcy (the turbulent flow factor), D. Use the real gas pseudo pressure function given in Question 5.

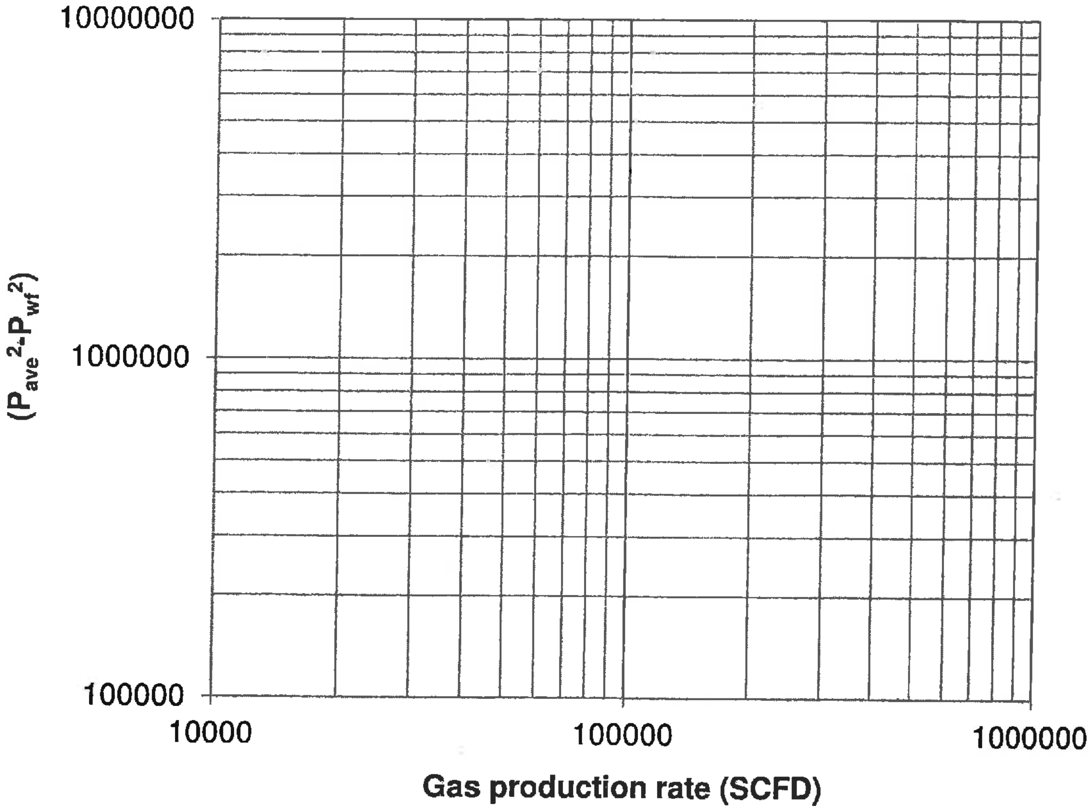
Initial pressure, p_i	2500 psia;
Reservoir Temperature, T	610°R;
Formation thickness, h	50 ft;
Porosity, ϕ	0.10;
Well radius, r_w	0.3 ft;
Gas viscosity, μ_i	0.02 cp;
Gas isothermal compressibility, c_{ti}	0.0004 psi^{-1}.



Question 7 (20 Marks)

The following flow rate and bottom-hole pressure information was obtained from a back-pressure test on a gas well in a dry gas reservoir with an average reservoir pressure of 3000 psia. Use the log-log chart given in the following to calculate the deliverability equation for the gas well and the absolute open flow (AOF).

Rate (SCFD)	p_{wf}(psia)
70693	2800
125649	2550
152735	2400
169068	2300


10000000
1000000
100000
$(P_{ave}^2 - P_{wf}^2)$
10000
100000
1000000
Gas production rate (SCFD)

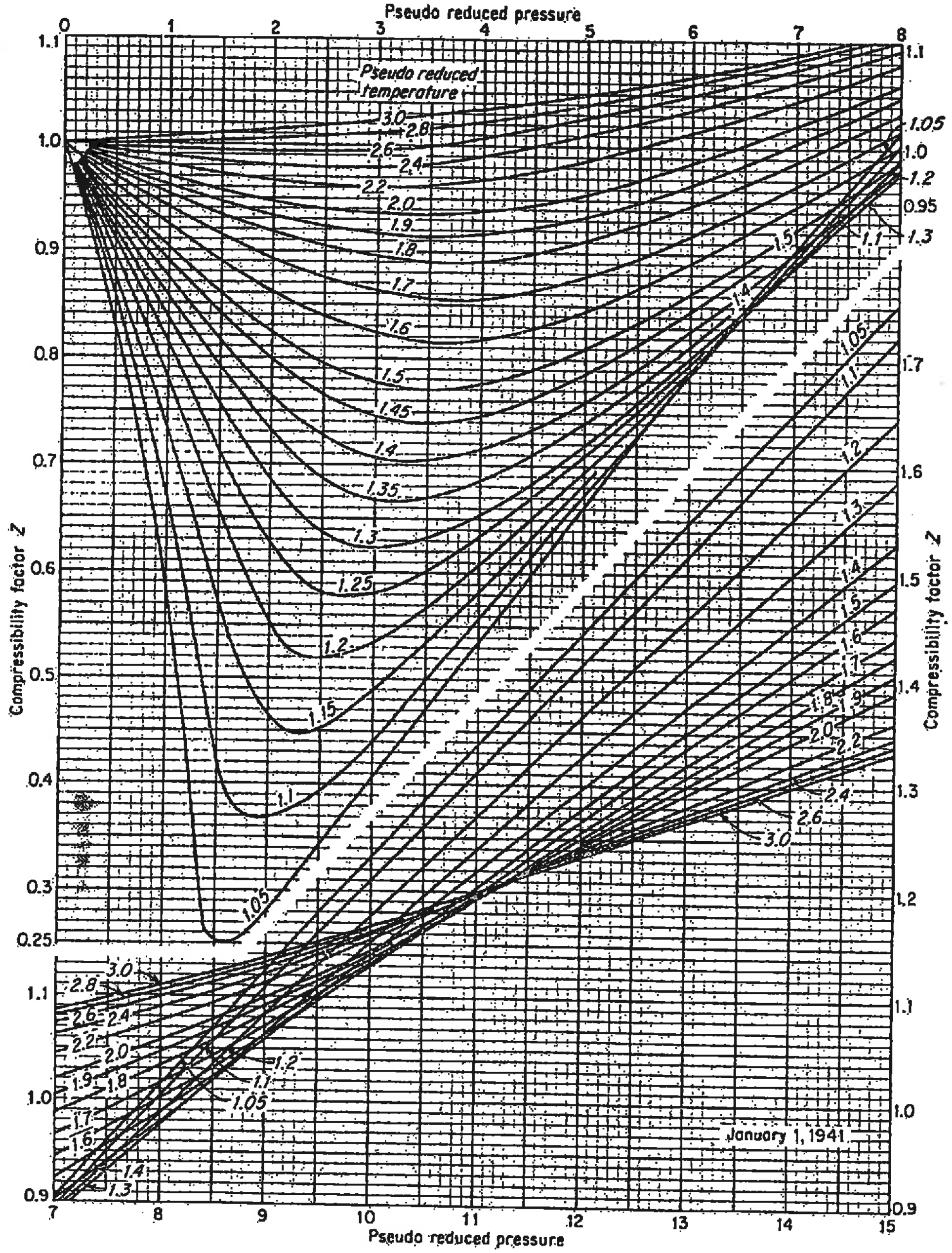
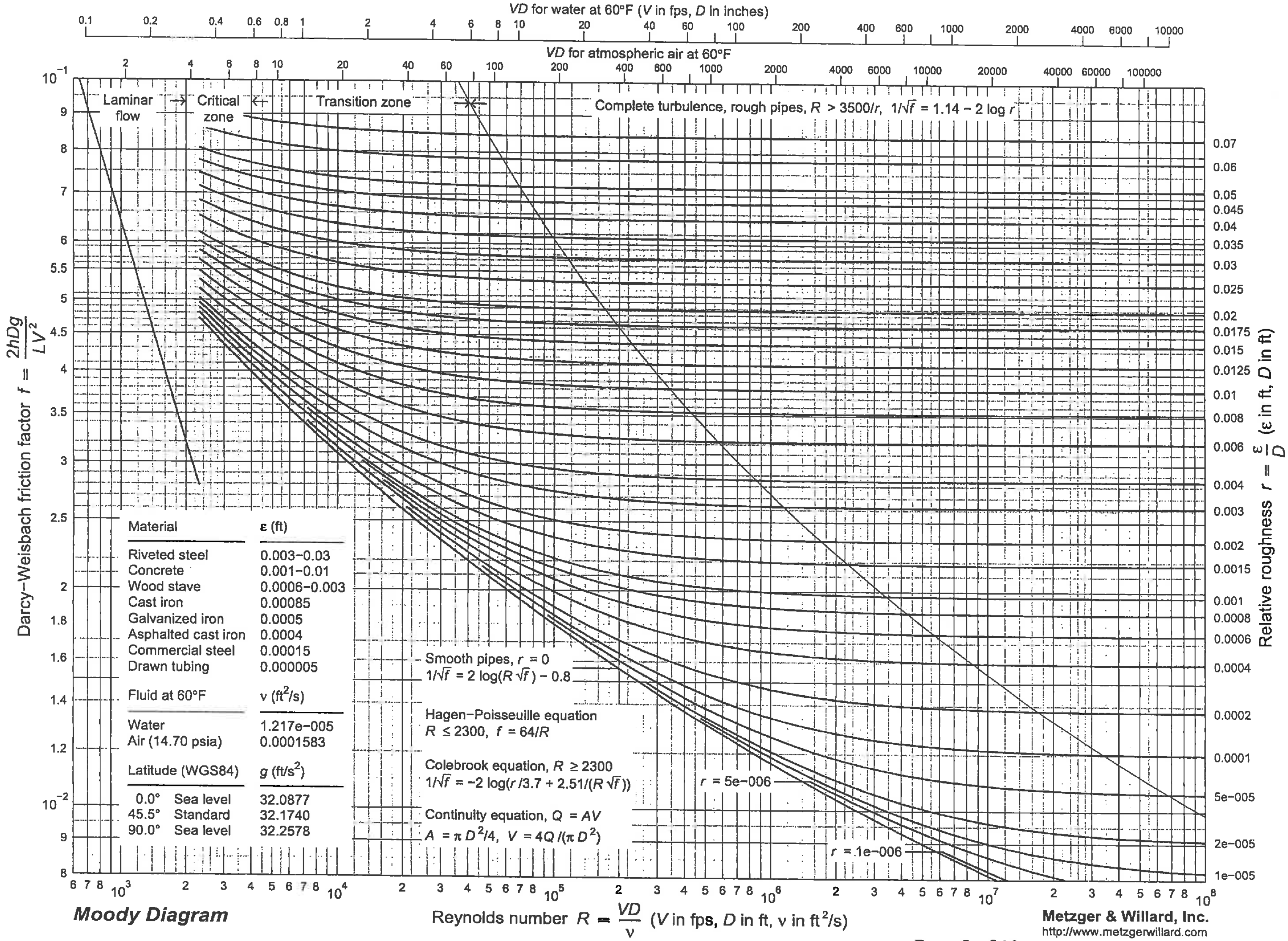


Fig. 4-16. Compressibility factor for natural gases. (*Standing and Katz, 4-87. Courtesy AIME.*)



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Formula Sheet

Gas properties:

$M_a = \sum y_i M_i$, where y is mole fraction and M is molecular weight in lb_{mass}/lb_{mole},

$\gamma_g = \frac{M_a}{M_{air}}$, γ_g is gas specific gravity (Air=1),

$T_{pc} = 169.2 + 349.5\gamma_g - 74.0\gamma_g^2$, T_{pc} is the pseudo critical temperature,

$p_{pc} = 756.8 - 131.0\gamma_g - 3.6\gamma_g^2$, pc is the pseudo critical pressure,

Correction for N_2, H_2S, and CO_2: $T'_{pc} = T_{pc} - 80y_{CO_2} + 130y_{H_2S} - 250y_{N_2}$

Correction for N_2, H_2S, and CO_2: $p'_{pc} = p_{pc} + 440y_{CO_2} + 600y_{H_2S} - 170y_{N_2}$

$T_r = \frac{T}{T'_{pc}}$, $p_r = \frac{p}{p'_{pc}}$

T_r and p_r are reduced pseudo critical temperature and pressure, respectively.

$\rho = \frac{pM}{ZRT}$ where ρ is gas density in lb_{mass}/ft^3, p in psia, *T* in *R*, *M* is in lb_{mass}/lb_{mole}, *R*=10.732 psi-$ft^3/(lb_{mol}$-°R)

Gas formation volume factor, $B_g = 0.02827\frac{ZT}{p}$ in $\frac{ft^3}{SCF}$, where p in psia, *T* in °*R*.

Pipeline flow capacity equations:

$$q = \frac{1.149\times10^6 T_{sc}}{p_{sc}}\left[\frac{p_1^2 - p_2^2}{\gamma_g f T Z L}\right]^{0.5} d^{2.5}$$ where *T* in K, *d* in m, *L* in m, q in m^3/day, T_{sc}=288 K, p_{sc}=101.325 kPa,

$N_{Re} = \frac{17.96\gamma_g q}{\mu d}$ where q is in standard m^3/day, γ_g is the gas specific gravity (air = 1), d is diameter in m, μ is gas viscosity in Pa - sec.

Decline curve analysis

Exponential decline: $q = q_i e^{-Dt}$,

Harmonic decline: $q = q_i/(1 + Dt)$

Hyperbolic decline $q = q_i(1 + bDt)^{-1/b}$

Cumulative production $G_p = \int q dt$

where q is rate in MMSCFD, G_p is the cumulative production in MMSCF, t is time in day, *D* is the decline rate in 1/day, b is the hyperbolic exponent, and subscript *i* stands for the initial condition.

Transient flow equations in field units:

$\psi(r,t) = \psi_i - \frac{1.422 q_{sc} T}{kh} p_D$, $\eta = \frac{6.33k}{\phi \mu_i c_i}$, $t_D = \frac{\eta t}{r_w^2}$

$p_D = \frac{1}{2}(\ln t_D + 0.809)$ only if $t_D > 100$,

$\psi(r,t) = \psi_i - \frac{1.422 q_{sc} T}{kh} p_D$

where ψ is the real gas pseudo pressure in psi^2/cp, ϕ is porosity, t is time in day, t_D is the dimensionless time, k is permeability in Darcy, h is formation thickness in ft, r is radius in ft, p is pressure in psia, c is the isothermal compressibility in psi^{-1}, μ is the gas viscosity in cP, T is temperature in R, S is skin factor, and p_D is the dimensionless pressure. The subscript *i* denotes the initial condition.

Gas wells drawdown Test

Slope of the semilog-plot: $m = \frac{1637 q_g T}{kh}$, q_g is in MSCFD, T is °R, k in mD, h in ft.

Test skin factor: $S' = 1.151\left(\frac{\psi_i - \psi(\Delta t = 1hr)}{|m|} - \log\left(\frac{k}{\phi \mu_i c_{ti} r_w^2}\right) + 3.23\right)$, where S' is the test skin factor, c is the gas isothermal compressibility in psi^{-1}, μ is the gas viscosity in cP, and ϕ is porosity

True skin factor: S'=S+Dq, where D is the non-Darcy or turbulent factor in 1/MSCFD

Gas wells deliverability equation:

$q = C(\bar{p}^2 - p_{wf}^2)^n$ where $\bar{p}$ is the average reservoir pressure, and p_{wf} is the stabilized flowing wellbore pressure, q is the gas production rate, *C* is the coefficient of the equation in any consistent systems of unit and n is an exponent.

Conversion Factors

1 m^3 = 6.28981 bbl =35.3147 ft^3
1acre = 43560 ft^2
1ac-ft = 7758 bbl
1Darcy = 9.869233×10^{-13} m^2
1 atm =14.6959488 psi =101.32500 kPa=1.01325 bar
1 cP = 0.001 Pa-sec
1 m = 3.28084 ft = 39.3701 inch