National Exams May 2016

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. Any non-communicating calculator is 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

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

a) Gas formation volume factor
b) Volumetric gas reservoir
c) Residual gas saturation to water
d) Water influx
e) Constant composition expansion (CCE) test
f) Stock-tank liquid
g) Gas recycling
h) Natural gas storage
i) Gas reserve
j) Orifice meter

Question 2 (20 Marks)
For a natural gas of the following composition:

Components	Mole %	MW (lb_{mass}/lb_{mole})
Methane	90	16.04
Ethane	5	30.07
Nitrogen	5	28.01

Calculate:
a) The pseudocritical temperature and pressure
b) The gas density at 600 psia and 100°F.
c) The gas formation volume factor at 600 psia and 100°F.
d) Gas velocity in a 16 inch (ID) pipeline operated at an average pressure of 600 psia and an average temperature of 100 °F when gas flow rate is 10 MMSCFD. Standard pressure and temperature are 14.7 psia and 60°F, respectively.

Question 3 (20 Marks)
Use the following information to advise on suitability of a 12 inch (ID) pipeline to deliver 24 MMSCFD of natural gas.

Length of pipeline, 100 miles,
Standard pressure, 14.7 psia,
Standard temperature, 60°F,
Pipeline inlet pressure, 400 psia,
Pipeline outlet pressure, 200 psia,
Gas specific gravity, 0.6 (air=1),
Average operating pressure, 60 °F,
Pipeline roughness, 0.0006 inch,
Gas viscosity, 0.011 cp,
Average gas deviation factor, 0.90.

Question 4 (20 Marks)
A volumetric dry gas reservoir has the fluid properties and reservoir data given in the following.

Initial pressure, 3000 psia,
Gas deviation factor at initial pressure, 0.80
Abandonment pressure, 500 psia,
Gas deviation factor at abandonment pressure, 0.96,
Initial gas saturation, 0.30,
Reservoir temperature, 200 °F,
Reservoir bulk volume, 20000 acre-ft,
Reservoir porosity, 0.30,
Residual gas saturation, 0.25.

a) Calculate the original gas in place in standard cubic feet (SCF) and gas recovery factor.
b) If the reservoir is under a strong water drive that maintain the original reservoir pressure, what recovery factor might be anticipated?

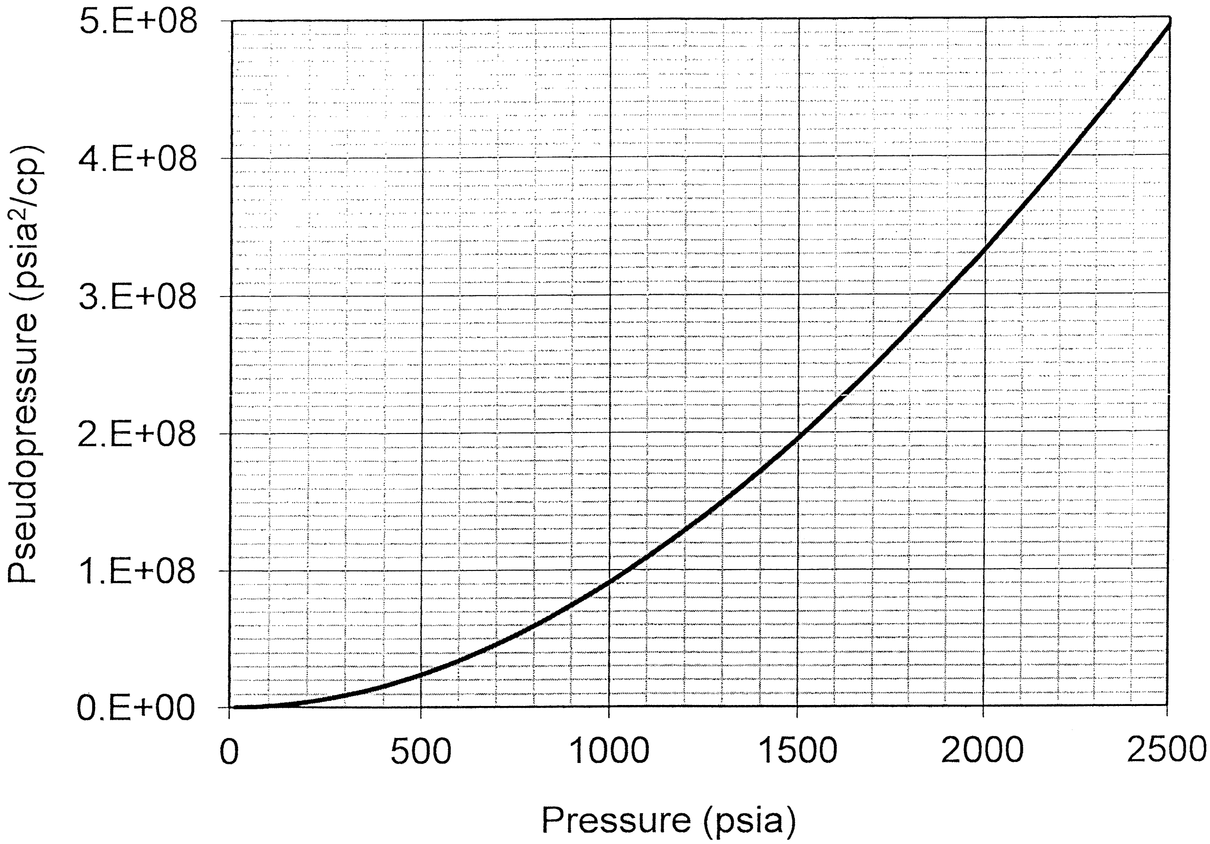
Question 5 (20 Marks)
A gas well with an exponential decline rate of 0.01/month currently produces 10 MMSCFD.

a) What will its production rate be in 2 years?
b) What will its cumulative production be in those 2 years?
c) How long will it take to reach a rate of 1 MMSCFD?
d) What will total cumulative production be from the end of Year 10 to the end of Year 11?

Question 6 (20 Marks)

A gas well in an infinite reservoir was produced at constant rate of 7 MMSCFD. Use reservoir date and the real gas pseudo pressure plot given in the following to find well bottom hole pressure after 36 hr of production.

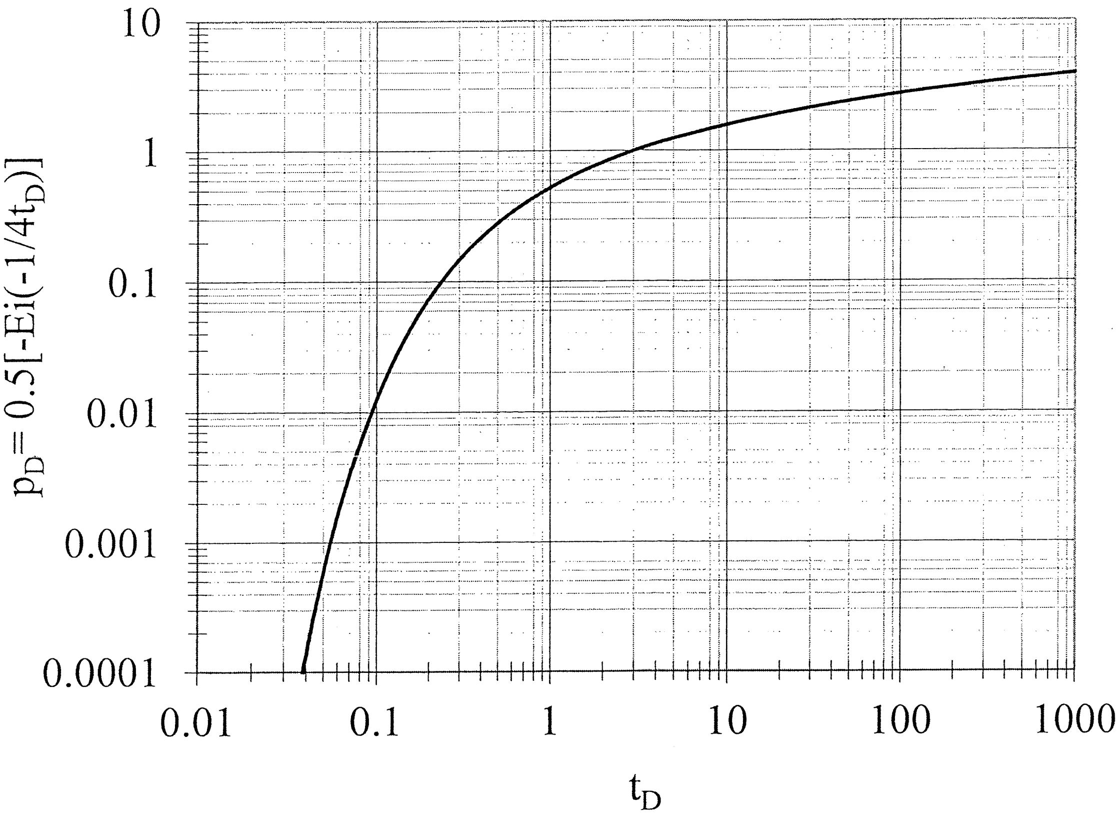
Initial pressure, p_i	2000 psia;
Formation thickness, h	39 ft;
Gas viscosity, μ	0.0158 cP;
Porosity, ϕ	0.15;
Permeability, k	20 mD;
Well radius, r_w	0.4 ft;
Gas isothermal compressibility, c_i	0.00053 psi^{-1}.



Question 7 (20 Marks)

A back pressure test was conducted on a gas well located in a reservoir that had an average pressure of 352.4 psia. The well was flowed on four choke sizes (four flow rates), and the flow rates and the flowing wellbore pressures were measured for each choke size. Using the given data find the stabilized deliverability equation for this well and the absolute open flow (AOF).

Flow period	Rate (MSCFD)	p_{wf}(psia)
1	965	337.6
2	2500	310.5
3	3390	291.9
4	4318	270.5



Plot of dimensionless pressure versus dimensionless time

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 in degree R,

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

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-ft³/(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.

Standard condition: T_{sc}=60 °F, p_{sc}=14.7 psia.

Pipeline flow capacity equations:

$q_{sc} = 5.634\left(\frac{T_{sc}}{p_{sc}}\right)\sqrt{\frac{(p_1^2 - p_2^2)d^5}{f\gamma_g Z_{av} TL}}$ where T in °R, d in inch, L in ft, q in MSCFD.

$N_{Re} = 710.39\frac{p_{sc}}{T_{sc}}\frac{\gamma_g q_{sc}}{\mu d}$ q in MSCFD, viscosity in cP, d in inches.

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 SCFD, G_p is the cumulative production in SCF, t is time in day , D is the decline rate in 1/day 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 qsc is gas rate in MSCFD, 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 build up 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: $S' = 1.151\left(\left(\frac{\psi_{1hr} - \psi_{wf}(\Delta t = 0)}{m}\right)_{1hr} - \log\left(\frac{k}{\phi \overline{\mu} c_t r_w^2}\right) + 3.23\right)$ 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

Gas wells deliverability equation:

$q = C(\overline{p}^2 - p_{wf}^2)^n$ where $\overline{p}$ 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.

<u>Conversion Factors</u>

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 = 0.000621371 mile

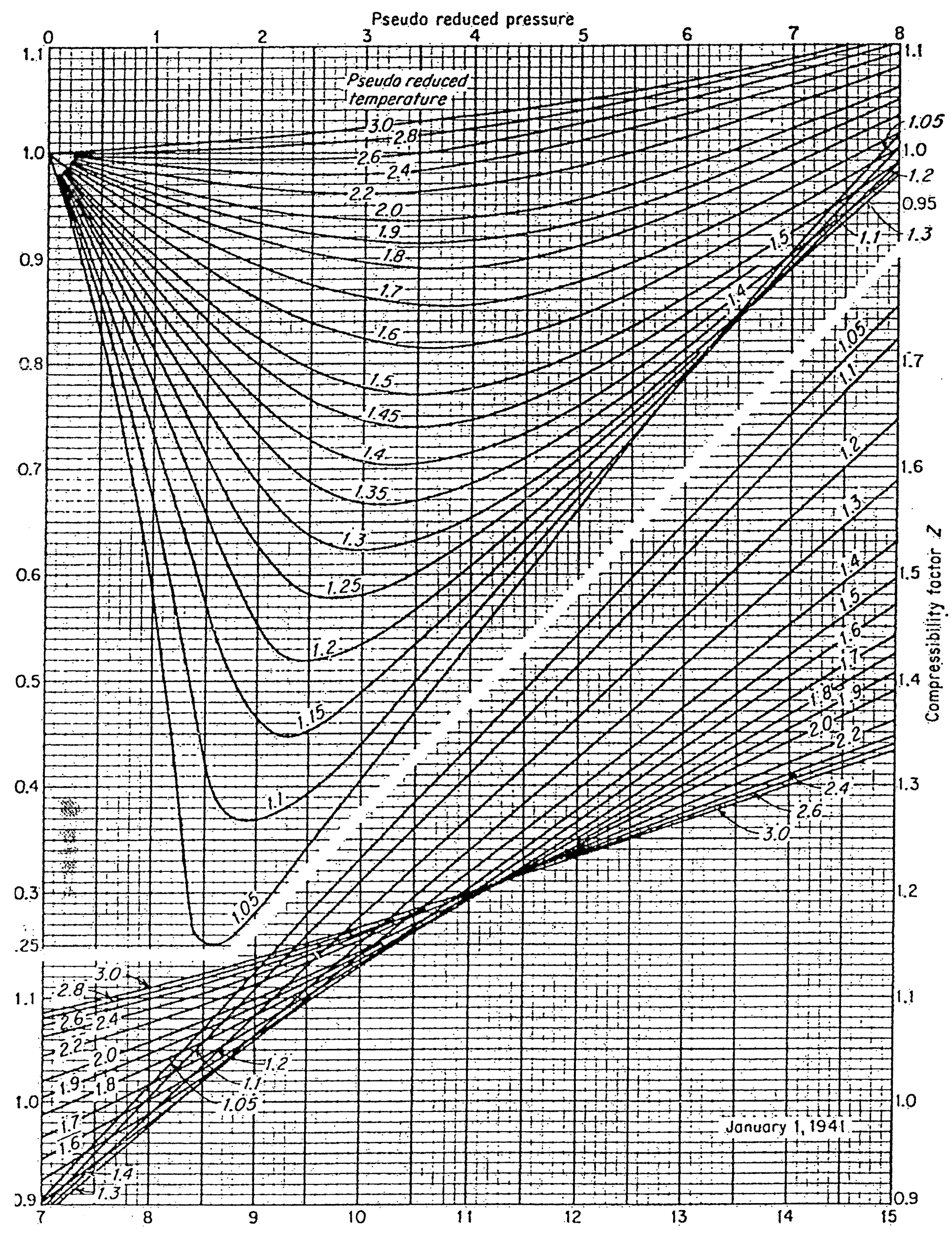
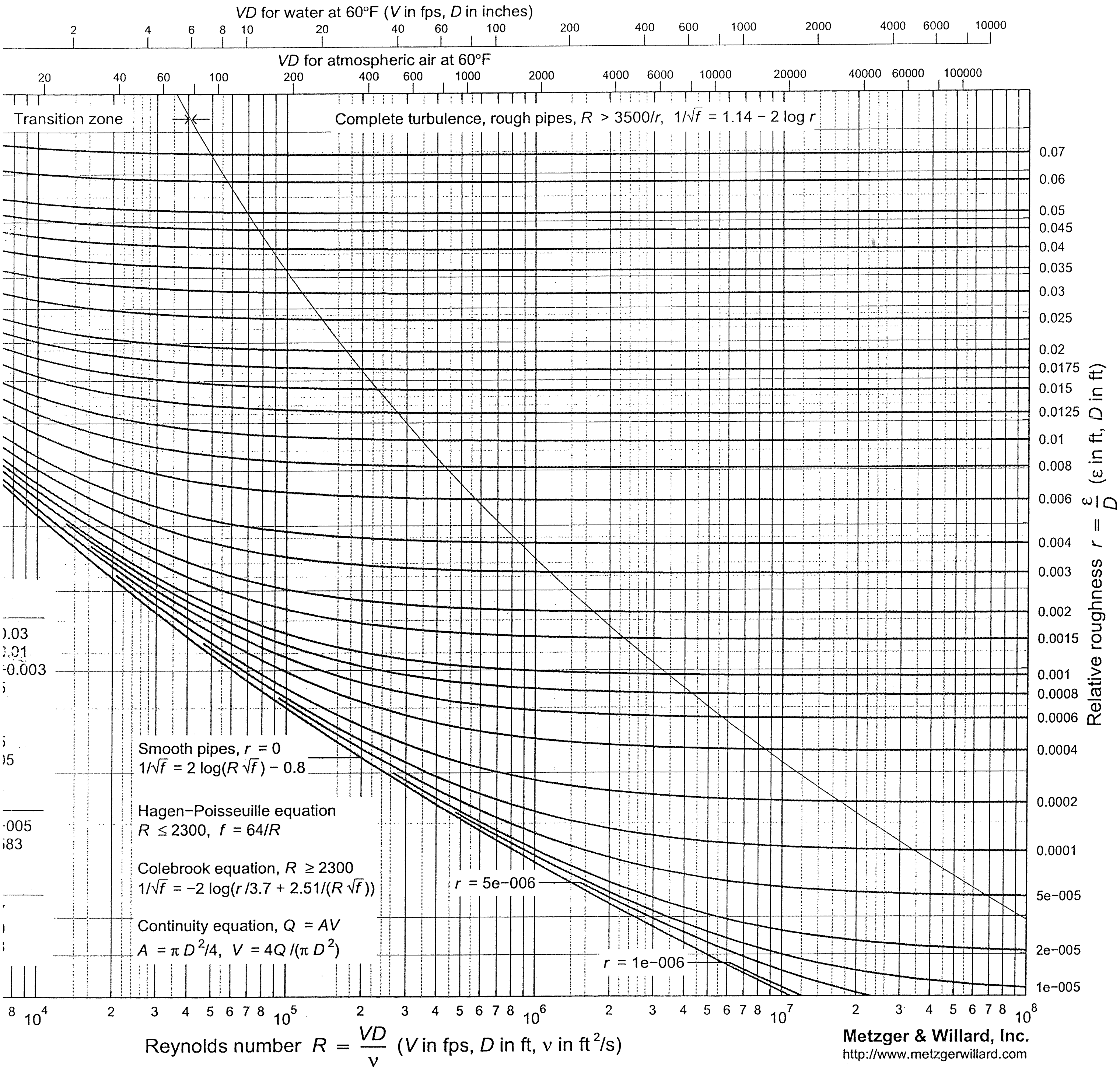


Fig. 4-16. Compressibility factor for natural gases. (*Standing and Katz, 4-87. Courtesy AIME.*)


VD for water at 60°F (V in fps, D in inches)
VD for atmospheric air at 60°F
Transition zone
Complete turbulence, rough pipes, R > 3500/r, 1/√f = 1.14 − 2 log r
Smooth pipes, r = 0
1/√f = 2 log(R √f) − 0.8
Hagen−Poiseuille equation
R ≤ 2300, f = 64/R
Colebrook equation, R ≥ 2300
1/√f = −2 log(r /3.7 + 2.51/(R √f))
Continuity equation, Q = AV
A = π D²/4, V = 4Q /(π D²)
r = 5e−006
r = 1e−006
Relative roughness r = ε/D (ε in ft, D in ft)
Reynolds number R = VD/ν (V in fps, D in ft, ν in ft²/s)
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