National Exams December 2015

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) Residual gas saturation to water
b) Non-Darcy flow
c) Net pay thickness
d) Abandonment pressure
e) Constant volume depletion (CVD) test
f) Flow-after-flow test
g) Separator test
h) Looped pipeline
i) Gas well liquid loading
j) Gas lift operation

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

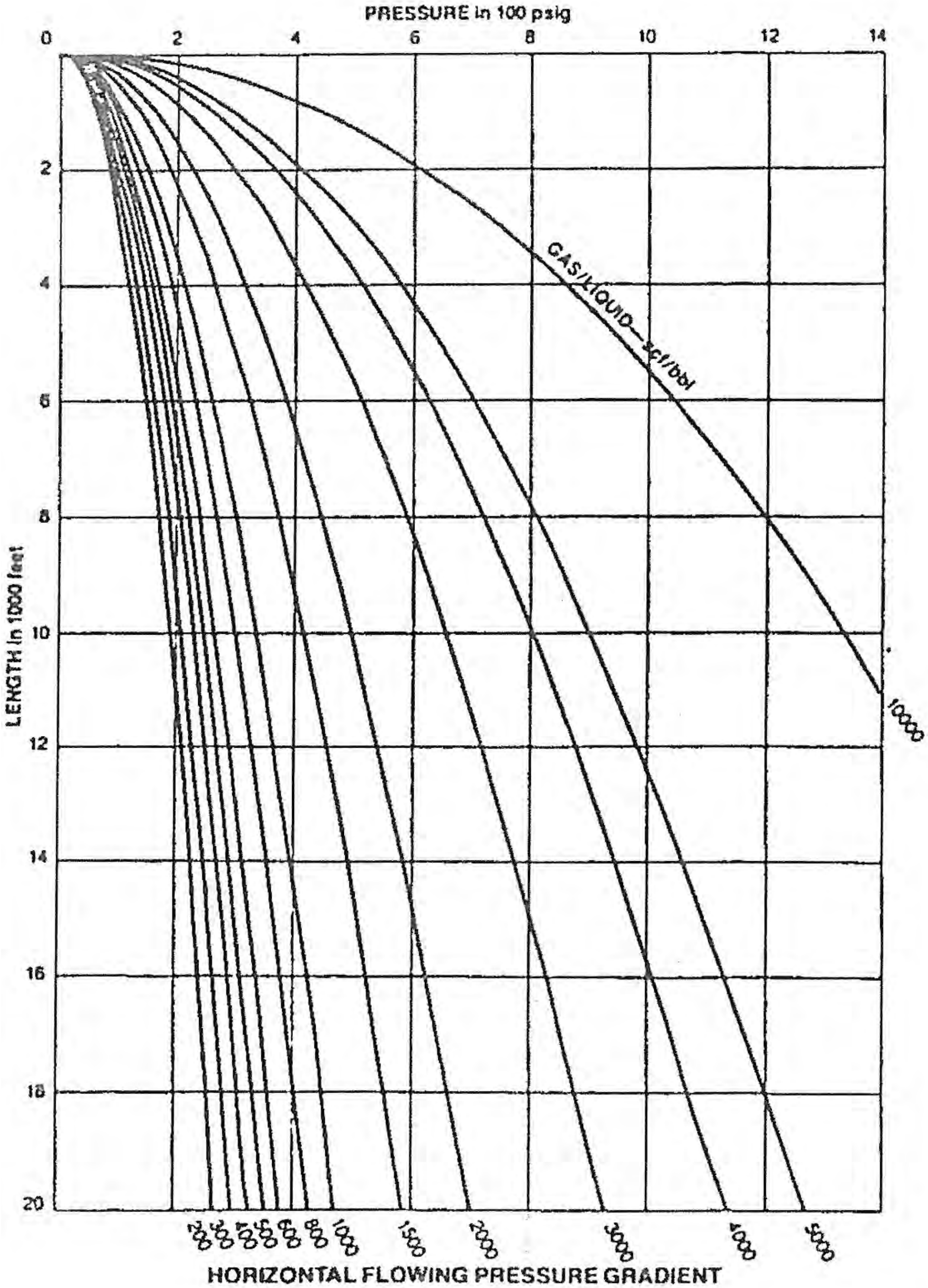
Components	Mole %	MW (lb_{mass}/lb_{mole})
Methane	92.67	16.04
Ethane	5.29	30.07
Propane	1.38	44.11
i-butane	0.18	58.12
n-butane	0.34	58.12
n-pentane	0.14	72.15

Calculate:
a) The pseudocritical temperature and pressure
b) The gas density at 2500 psia and 200°F.
c) The gas formation volume factor at 2500 psia and 200°F.
d) The number of standard cubic feet of gas per acre foot of reservoir of 25% porosity and 10% connate water saturation at 2500 psia and 200°F. Standard pressure and temperature are 14.7 psia and 60°F, respectively.

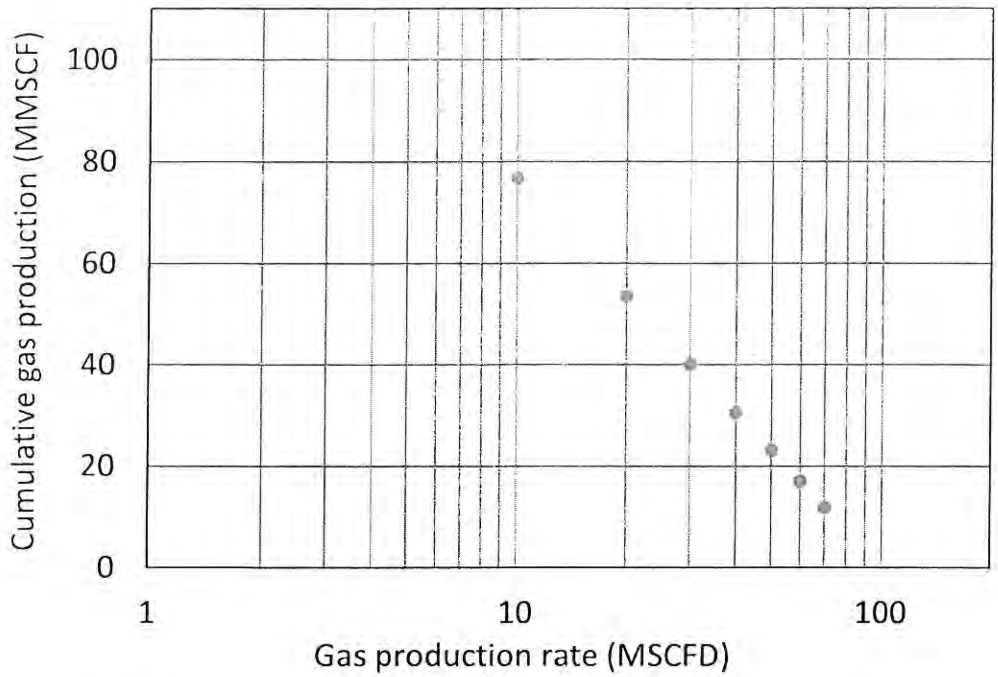
Question 3 (20 Marks)
Gas and liquids flow rates are measured using various techniques.
(a) Name four common techniques used in oil & gas industry to measure flow rates.
(b) Name four important factors for selection of the measurement techniques.
(c) Define accuracy and repeatability (precision) of a meter.
(d) Define rangeability and linearity of a meter.

Question 4 (20 Marks)
A horizontal 2.5 inch and 10000 ft long flow line connects a well to a production facility. The oil production rate is 800 STBD with a production GOR of 4000 SCF/STB and the flowing wellhead pressure is 1000 psia. Use the pressure traverse curve given in the following for oil rate of 800 STBD and 2.5 inch flow line to estimate the pressure at the production facility.

Solution: The pressure traverse gives surface facility pressure to be 650 psia.



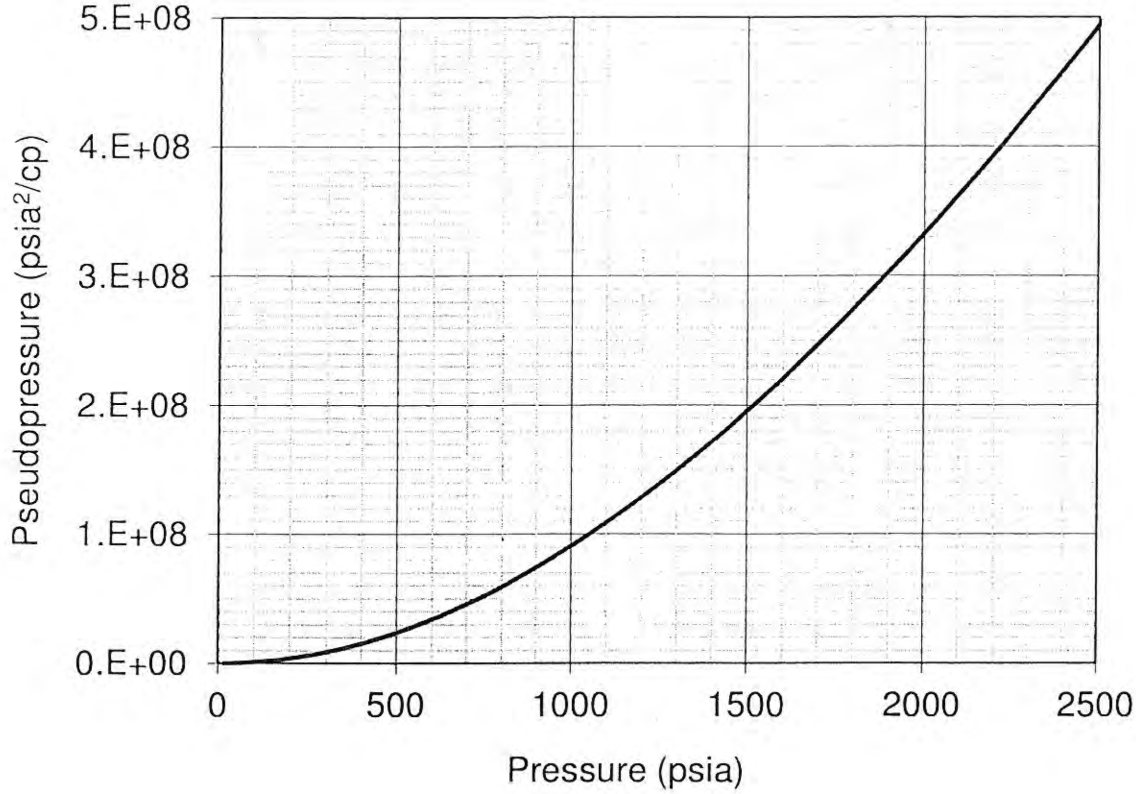
Question 5 (20 Marks)
Estimate the production life of a gas field for an economic limit of 5 MSCFD for production rate. Also, calculate cumulative production when the gas rate reaches the economic limit. The cumulative gas production versus log of gas production rate is shown below.



Question 6 (20 Marks)

A gas well, which is drilled at a location 500 ft far from a sealing fault, is open to production at a rate of 5 MMSCFD for one day. Use reservoir date and the real gas pseudo pressure plot given in the following to calculate well pressure after one day of production. Assume infinite acting behaviour except for the fault limitation.

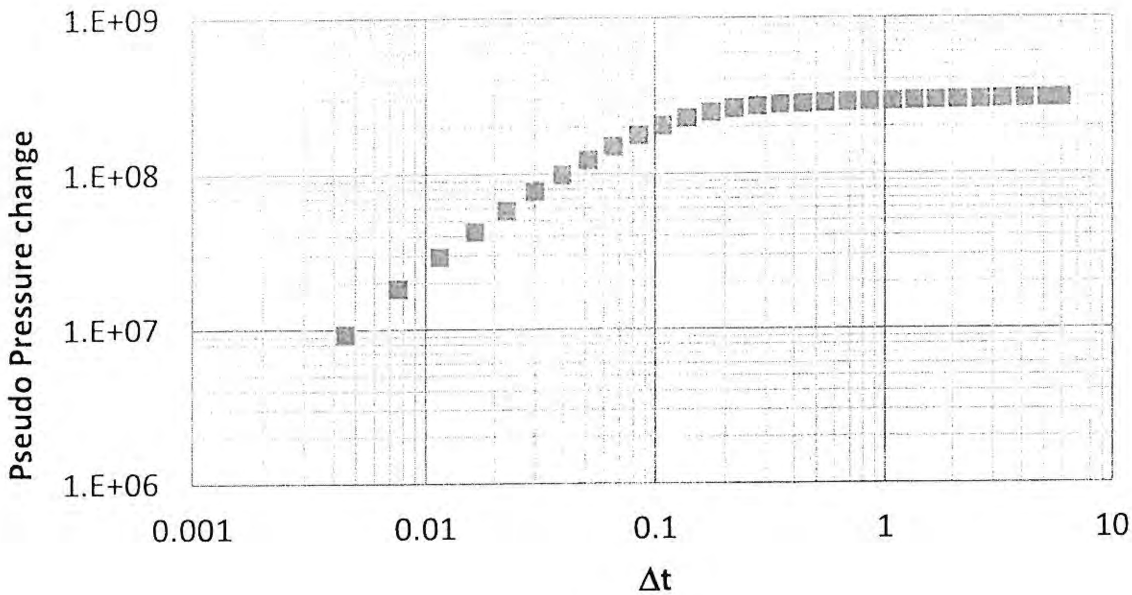
Initial pressure, p_i	2000 psia;
Reservoir Temperature, T	580°R;
Formation thickness, h	39 ft;
Gas viscosity, μ	0.0158 cP;
Porosity, ϕ	0.15;
Permeability, k	20 mD;
Well radius, r_w	0.4 ft;
Gas isothermal compressibility, c_i	0.00053 psi^{-1}.

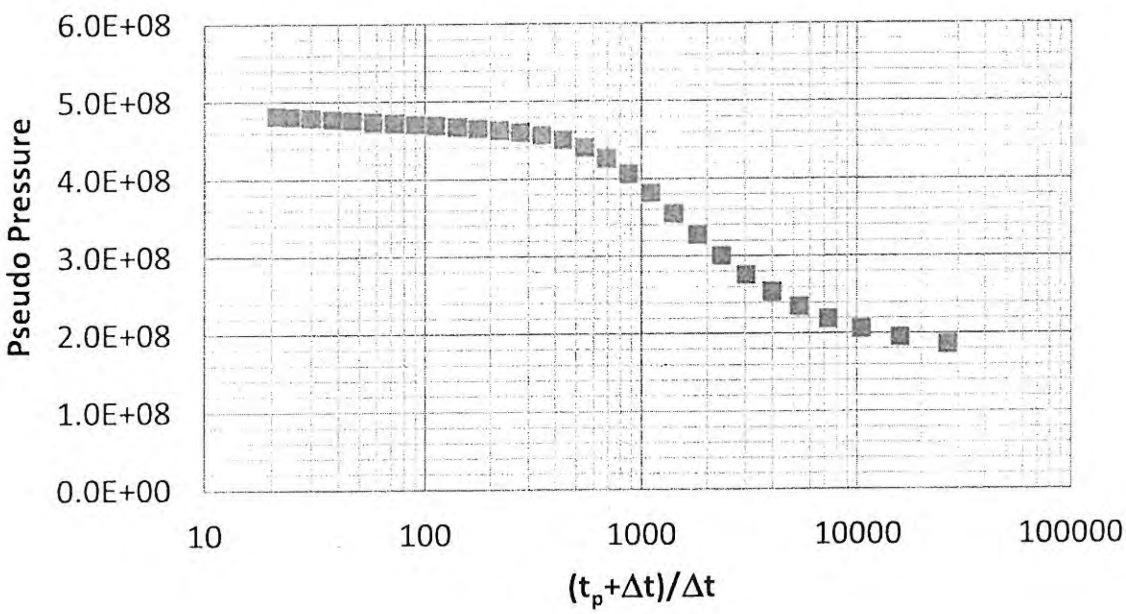


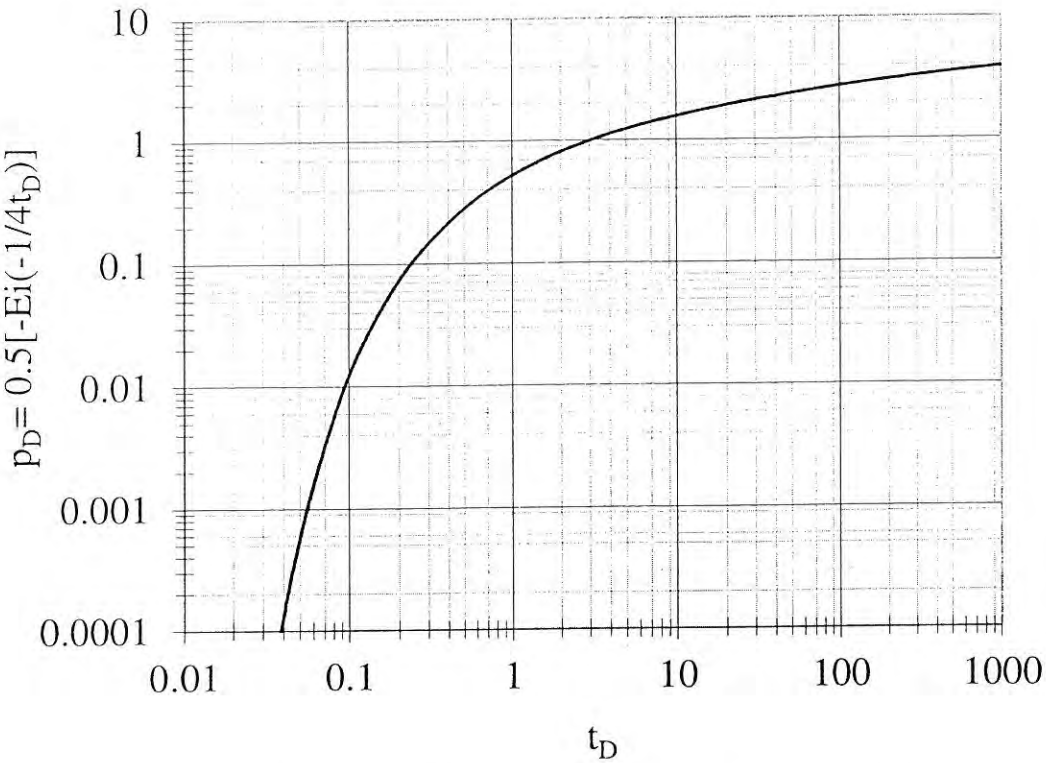
Question 7 (20 Marks)

Given the following formation and fluid properties, estimate formation permeability, skin factor, and end of wellbore storage from the buildup test data using gas pseudo pressure method. Log-log and semi-log plots are given in the following.

$p_{wf} = 1379$ psia,
$h = 45$ ft,
$r_w = 0.512$ ft,
$\phi = 0.105$,
$q = 9500$ MscfD,
$c_g = 8\times10^{-4}$ psia^{-1},
$c_w = 3\times10^{-6}$ psia^{-1},
$c_f = 6\times10^{-6}$ psia^{-1},
$S_{wc} = S_{wi} = 0.28$,
$\overline{\mu_g} = 0.02$ cp,
$\psi_{wf}(\Delta t = 0) = 1.73\times10^8$ psi^2/cp


1.E+09
1.E+08
1.E+07
1.E+06
Pseudo Pressure change
0.001
0.01
0.1
1
10
Δt


6.0E+08
5.0E+08
4.0E+08
3.0E+08
2.0E+08
1.0E+08
0.0E+00
Pseudo Pressure
10
100
1000
10000
100000
(tp+Δt)/Δt



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-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*.

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: $S' = 1.151\left(\left(\frac{\psi_{1hr} - \psi_{wf}(\Delta t = 0)}{m}\right)_{1hr} - \log\left(\frac{k}{\phi \bar{\mu} c_t r_w^2}\right) + 3.23\right)$ 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:

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

<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

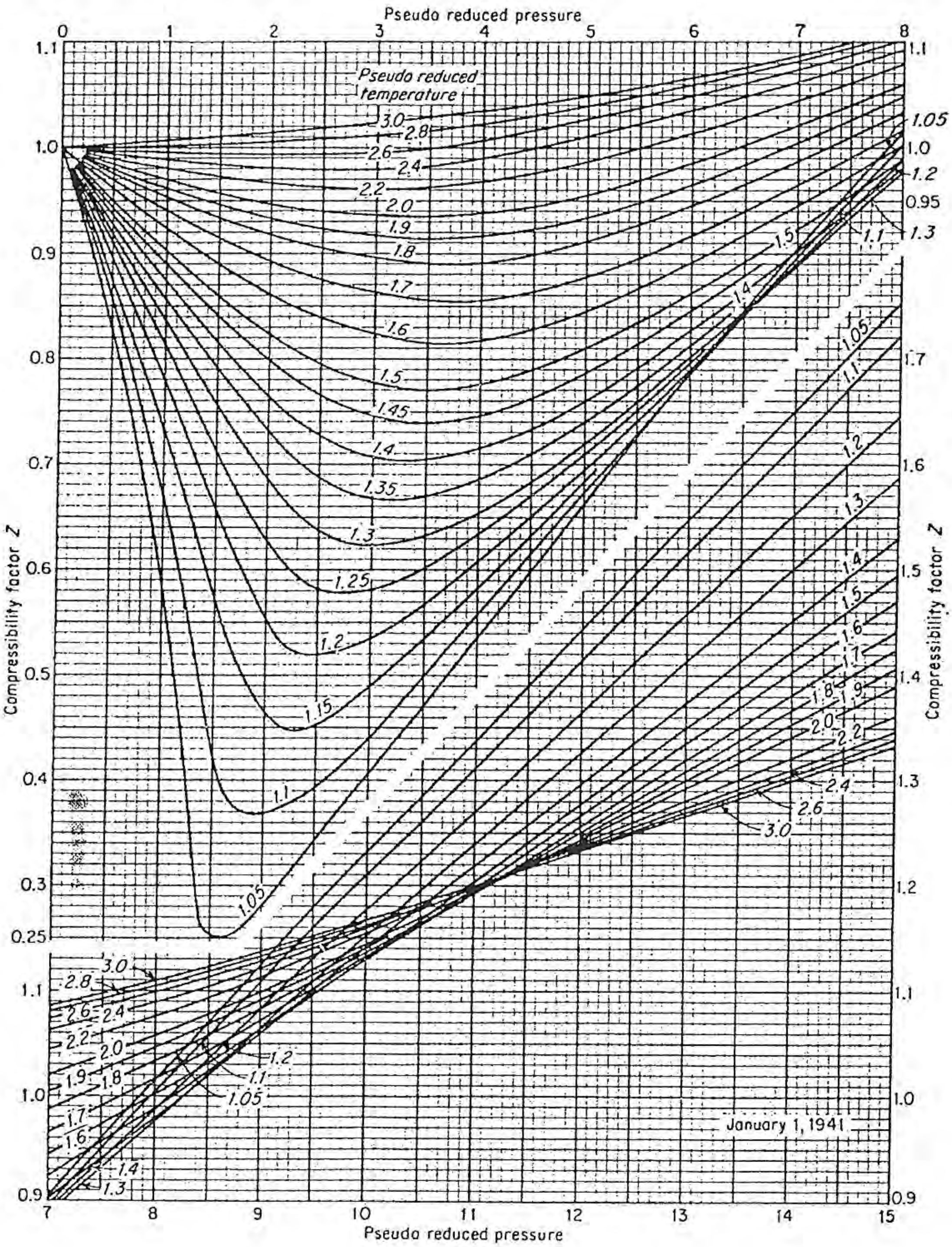


Fig. 4-16. Compressibility factor for natural gases. (*Standing and Katz, 4-87. Courtesy AIME.*)