National Exams May 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) Dry gas
b) Cricondenbar
c) Water content
d) Volumetric gas reservoir
e) Pigging operation
f) Gas formation volume factor
g) Well deliverability
h) Acid gas
i) Sour gas
j) Orifice meter

Question 2 (20 Marks)
A gas well is producing dry natural gas at a flow rate of 10 MMSCFD with the following well stream composition:

Component	Mole Fraction	Molecular Weight (lb_{mass}/lb_{mole})	P_{ci} (psia)	T_{ci} (°R)
Methane	0.92	16.04	666.4	343.33
Ethane	0.05	30.07	706.5	549.92
Propane	0.03	44.11	616.4	666.06

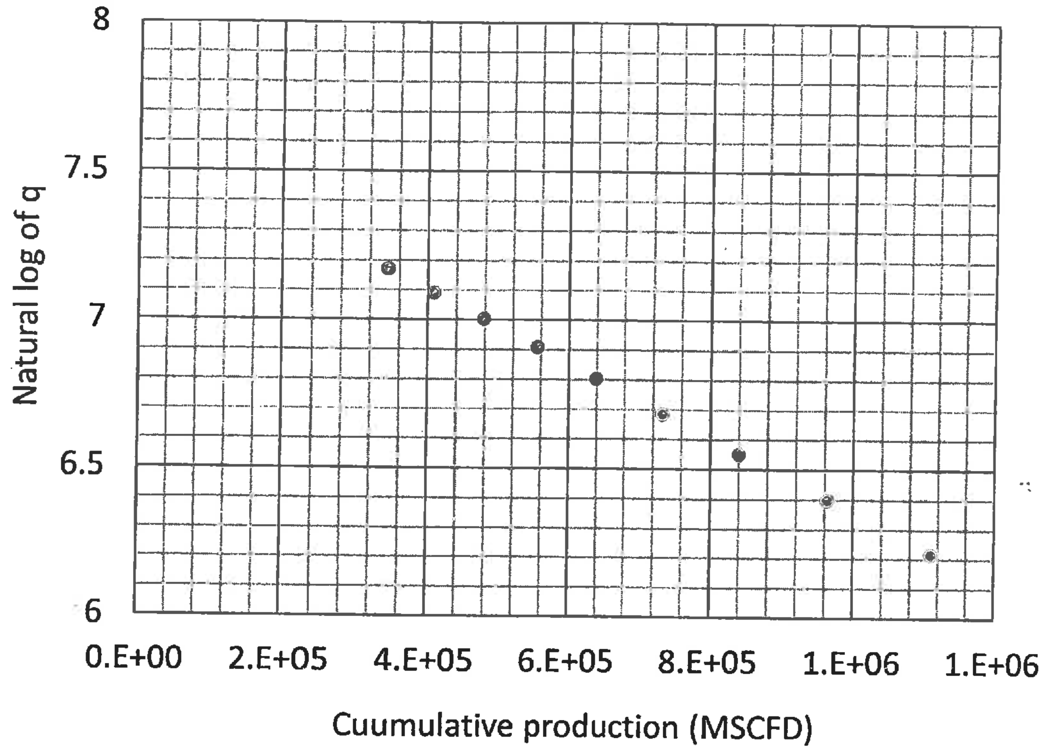
The gas well is flowing to the production facility using a flow line with an internal diameter of diameter of 4 inches and an average pressure and temperature are 2500 psia and 120 degree C, respectively. Calculate the average gas velocity inside the flow line in ft/sec.

Question 3 (20 Marks)
As a part of a gas injection project, produced natural gas with a specific gravity of 0.68 from a separation facility needs to be transported to another station located 20 km far from the gas production facility. The separation facility operating pressure and temperature are 1500 psia and 77 °F, respectively. Determine the diameter of the transportation line to handle gas flow rate of 220 MMSCFD and a delivery pressure of 1000 psia. Assume a pipe roughness of 0.0012 ft, an average viscosity of 0.015 cP, and an average gas compressibility factor of 0.85 for the natural gas. Show one step of your detailed calculations toward the solution.

Question 4 (20 Marks)

Natural log (ln) of gas production rate versus cumulative production rate available from a volumetric dry gas field producing under the boundary-dominated flow condition is given in the following. Note: unit for q in this plot is MSCFD.

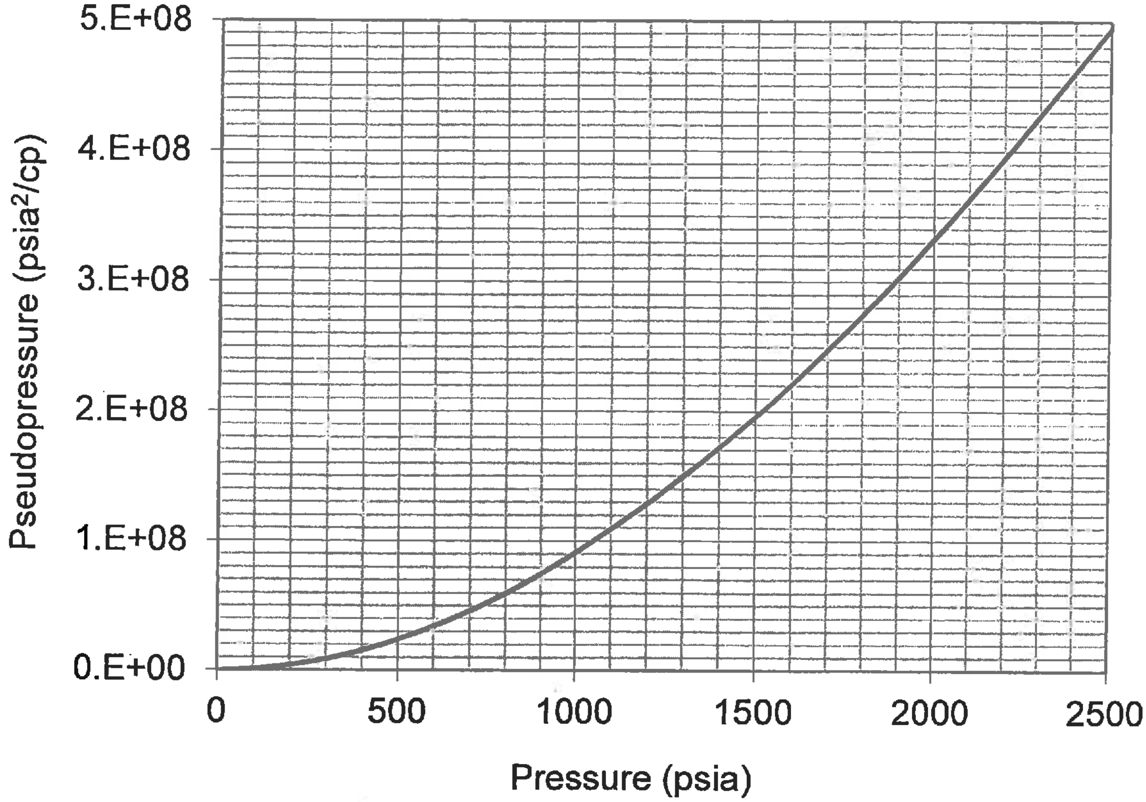
a) How long does it take to produce 2 MMMSCF of natural gas from this reservoir?
b) Calculate gas reserves if a minimum rate limit of 100 MSCFD is allowed for the gas field.



Question 5 (20 Marks)

A gas well is open to production at a rate of 7 MMSCFD for 36 hr. At this time the rate is increased to 21 MMSCFD for 72 hr (108 hr total production time for production). Use reservoir date and the real gas pseudo pressure plot given in the following to calculate well pressure after 108 hr of production of this well. Assume infinite acting behaviour.

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 6 (20 Marks)
Two separate flow tests have been conducted in a gas well and the following data has been obtained after interpretation of the tests.

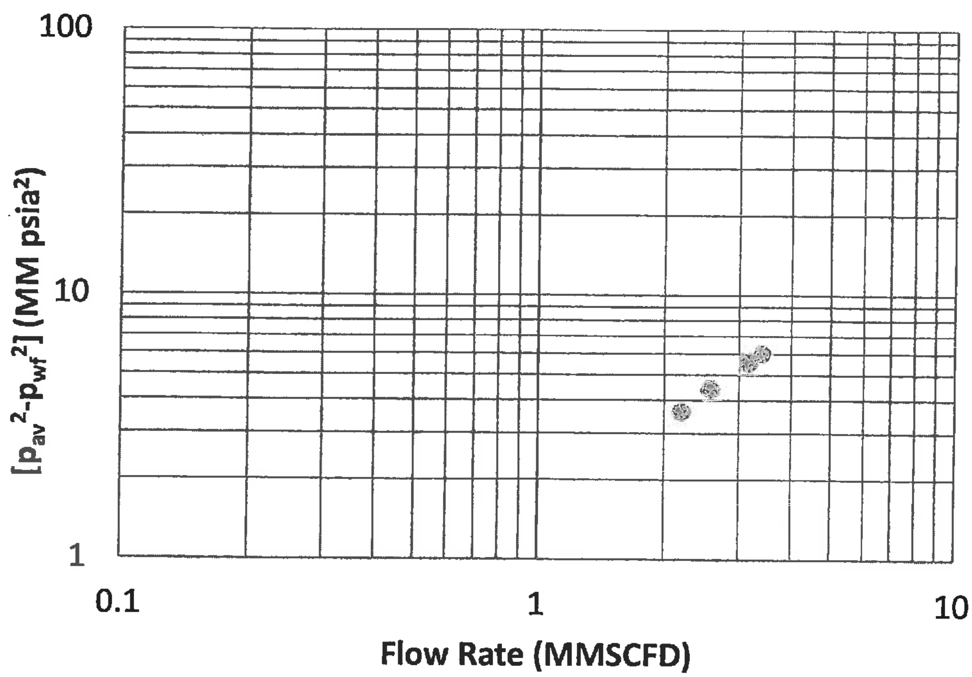
Test #	Rate (MMSCFD)	Skin factor
1	30	+1
2	50	+3

Calculate the true skin factor and the non-Darcy (the turbulent flow factor), D.
Do you recommend acidizing this gas well? Explain your results.

Question 7 (20 Marks)
A back pressure test has been conducted to determine the well deliverability. The following flow rate and bottom-hole pressure information was obtained from the test.

Flow period	Rate (MMSCFD)	Bottom hole flowing wellbore pressure (psia)
Shut-in	0	3884 (Average Reservoir Pressure)
1	2.19	3387
2	2.57	3268
3	3.16	3092
4	3.40	3015

Use the log-log chart given in the following to estimate the well deliverability at a bottom hole flowing pressure of 2500 psia.



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,

$p_{pc} = 756.8 - 131.0\gamma_g - 3.6\gamma_g^2$, p_{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*.

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 MSCFD, G_p is the cumulative production in MSCF, 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 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