National Exams May 2015

98-Pet-B5, Well Testing

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)

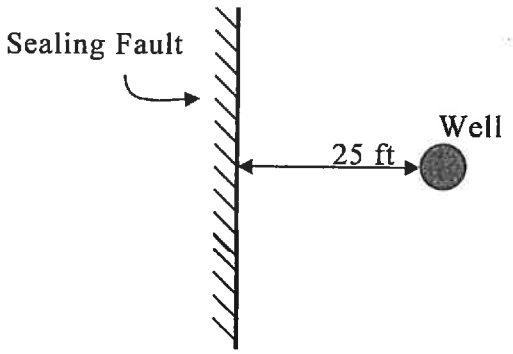
Explain (briefly in one or two sentences) the following concepts.

a) Infinite acting reservoir
b) Non-Darcy flow
c) Phase redistribution
d) Dimensionless time
e) Drill stem test
f) Pseudo steady state
g) Dual porosity reservoir
h) Fall off test
i) Drainage area
j) Horner time

Question 2 (20 Marks)

An oil well is producing at a constant rate of 500 STBD in an infinite reservoir. The seismic survey indicates a sealing fault at 25 ft of the well. Calculate the wellbore pressure after 5 days.

Wellbore radius, r_w= 0.25 ft,
Total compressibility, $c_t = 5\times10^{-5}$ psi^{-1},
Oil viscosity, μ_o= 2 cP,
Porosity, ϕ = 0.3,
Permeability, k = 250 mD,
Formation thickness, h = 20 ft,
Oil formation volume factor, B_o = 1.2 bbl/STB,
Initial pressure, p_i = 3000 psi.

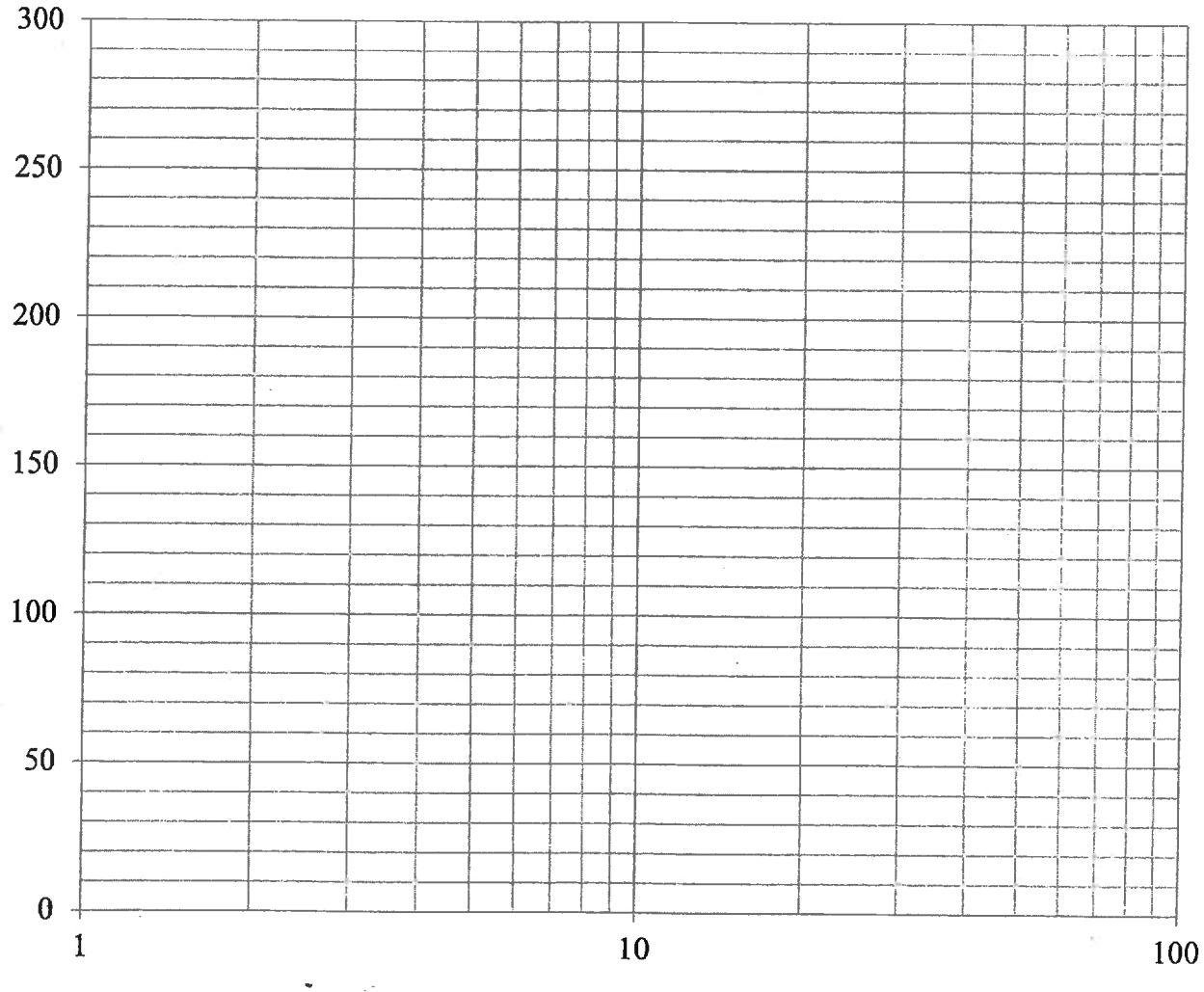


Question 3 (20 Marks)

A drawdown test has been conducted in an oil well and the following pressure data has been collected during the test. Estimate formation permeability and skin factor from the drawdown test data using the following reservoir and fluid properties. Required semi-log chart is given in the following.

Flow rate, $q = 90$ STBD,
Formation thickness, $h = 17$ ft,
Formation volume factor, $B_o = 1.1$ bbl/STB,
Initial reservoir pressure, $p_i = 1479$ psia,
Porosity, $\phi = 0.25$,
Total compressibility, $c_t = 7.65 \times 10^{-6}$ psi^{-1},
Oil viscosity, $\mu_o = 7.86$ cP,
Wellbore radius, $r_w = 0.21$ ft.

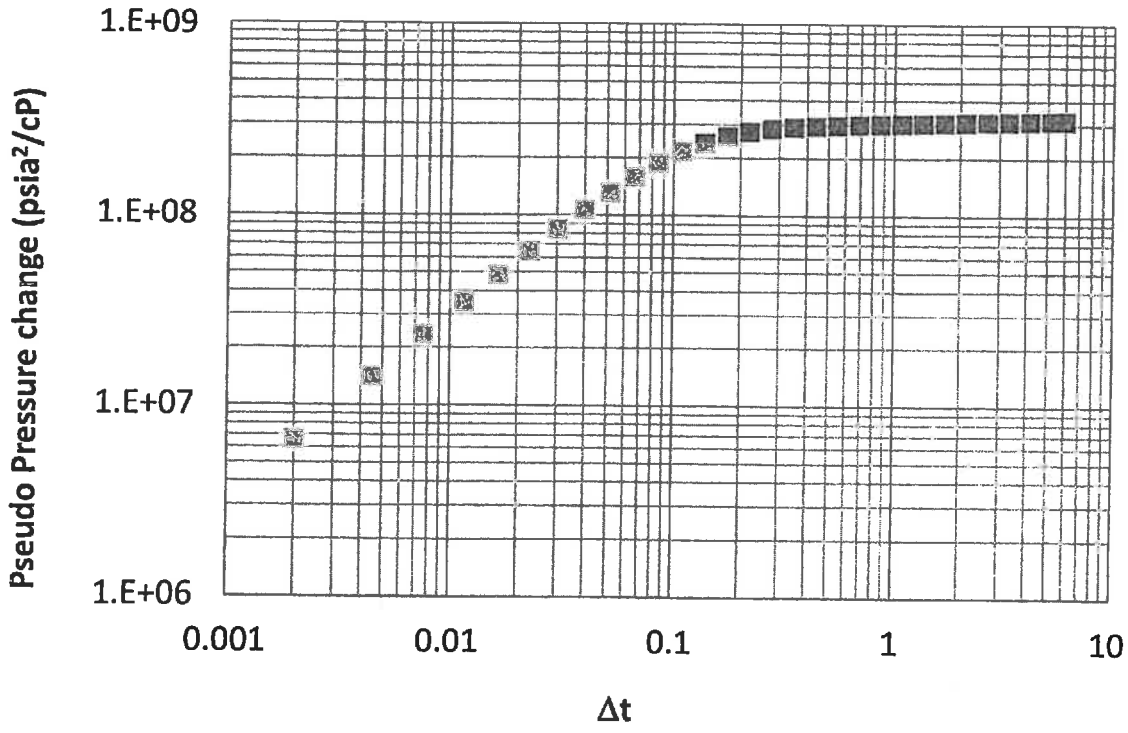
Time (hour)	p_{wf} (psia)
1	284
3	215
5	183
7	162
9	147
11	134
13	124
15	115

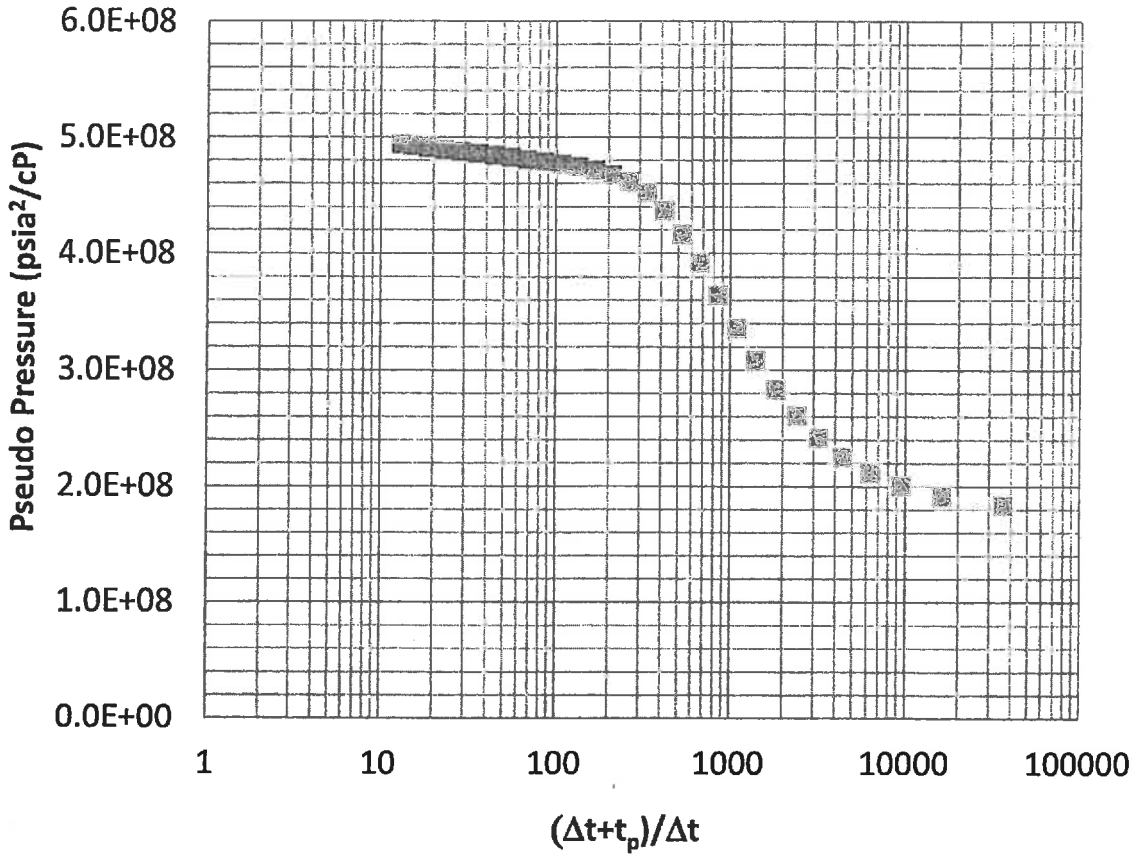


Question 4 (20 Marks)

Given the following test plots as well as formation and fluid properties for a gas reservoir, estimate the approximate end of wellbore storage, formation permeability and skin factor from the buildup test data using pseudo pressure method.

Flowing wellbore pressure prior to shut in, p_{wf}=1378.84 psia,
Pseudo pressure corresponding to p_{wf}, p_{pwf}, =1.77×10^{8} psia^2/cp,
Formation thickness, h=10 ft,
Gas specific gravity, γ_g=0.741 (air = 1.0)
Wellbore radius, r_w=0.46 ft
Formation temperature, T_f=108.9°F,
Porosity, ϕ=10.6%
Gas production rate, q_g=8000 MSCFD,
Total compressibility, c_t= 2.238 $\times10^{-4}$ psia^{-1}
Average gas viscosity μ_g= 0.02 cP
Production time prior to shut in, t_p=72 hr.

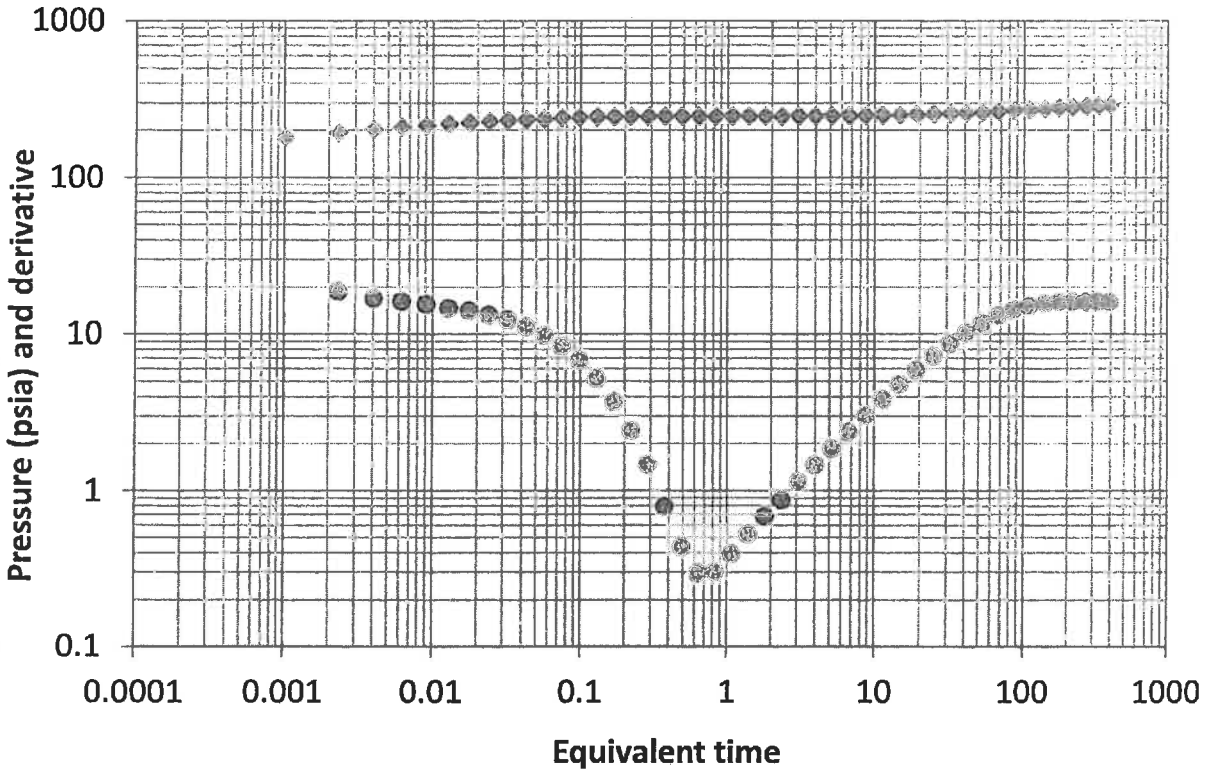


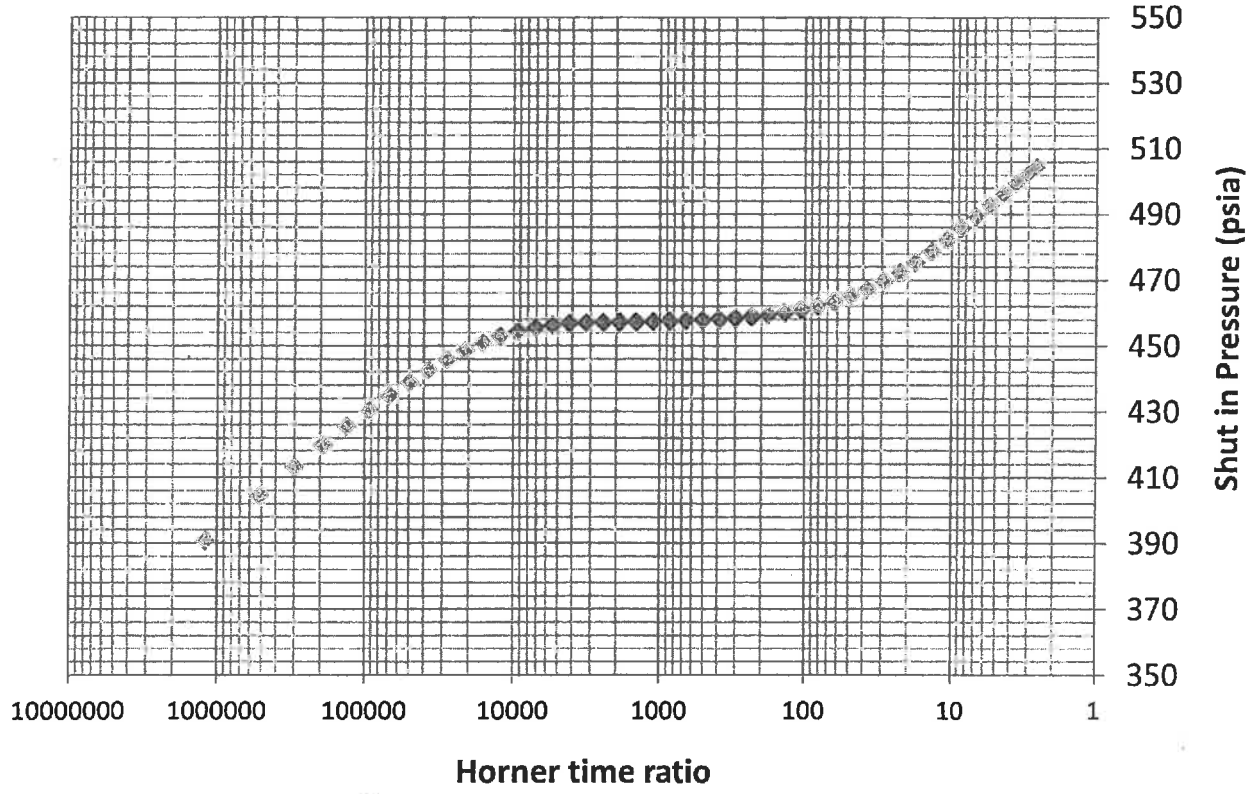


Question 5 (20 Marks)

A pressure build up has been conducted in an oil well in a naturally fractured reservoir. Pressure and derivative data are plotted in the following. Given the following formation and fluid properties estimate skin factor, initial reservoir pressure, and storativity (ω) from the buildup test data.

Oil production rate, q = 125 STB/D,
Formation thickness, h = 17 ft,
Oil formation volume factor, B_o = 1.054 rb/STB,
Production time prior to shut in, t_p = 1200 hr,
Formation porosity, ϕ = 13.0%,
Total compressibility, c_t =7.19 × 10^{-6} psi^{-1},
Flowing wellbore pressure prior to shut in, p_{wf}= 211.20 psia,
Wellbore radius, r_w =0.30 ft,
Oil viscosity, μ_o = 1.72 cp.


1000
100
10
1
0.1
Pressure (psia) and derivative
0.0001
0.001
0.01
0.1
1
10
100
1000
Equivalent time

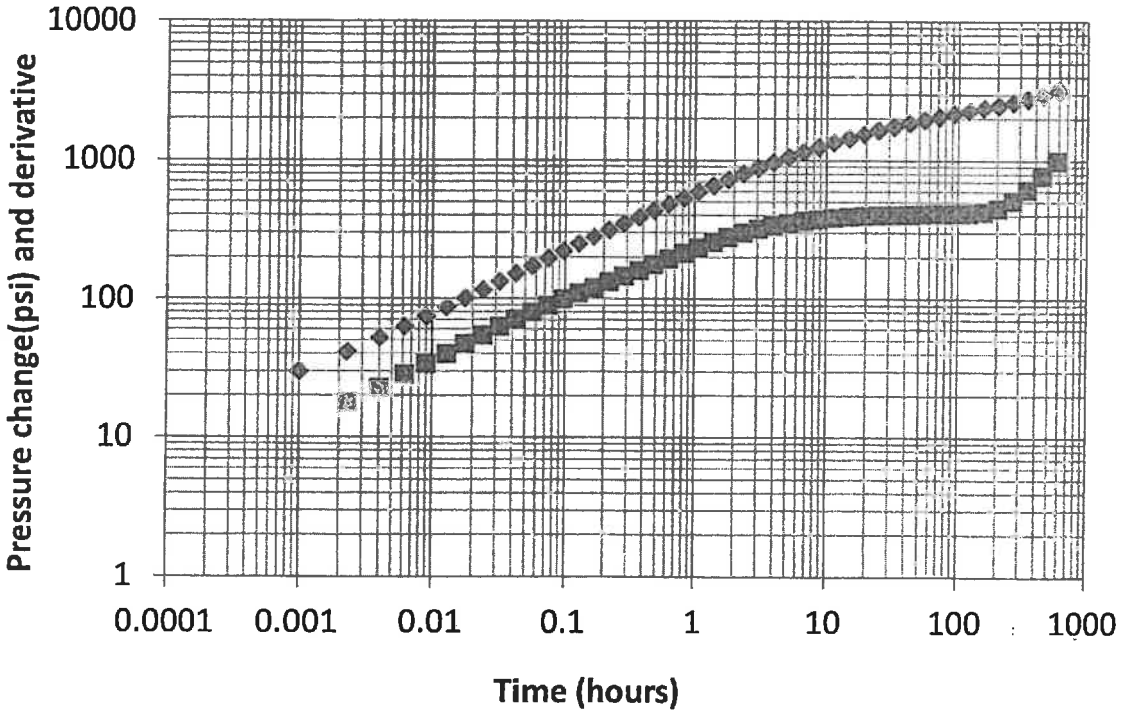

550
530
510
490
470
450
430
410
390
370
350
Shut in Pressure (psia)
10000000
1000000
100000
10000
1000
100
10
1
Horner time ratio

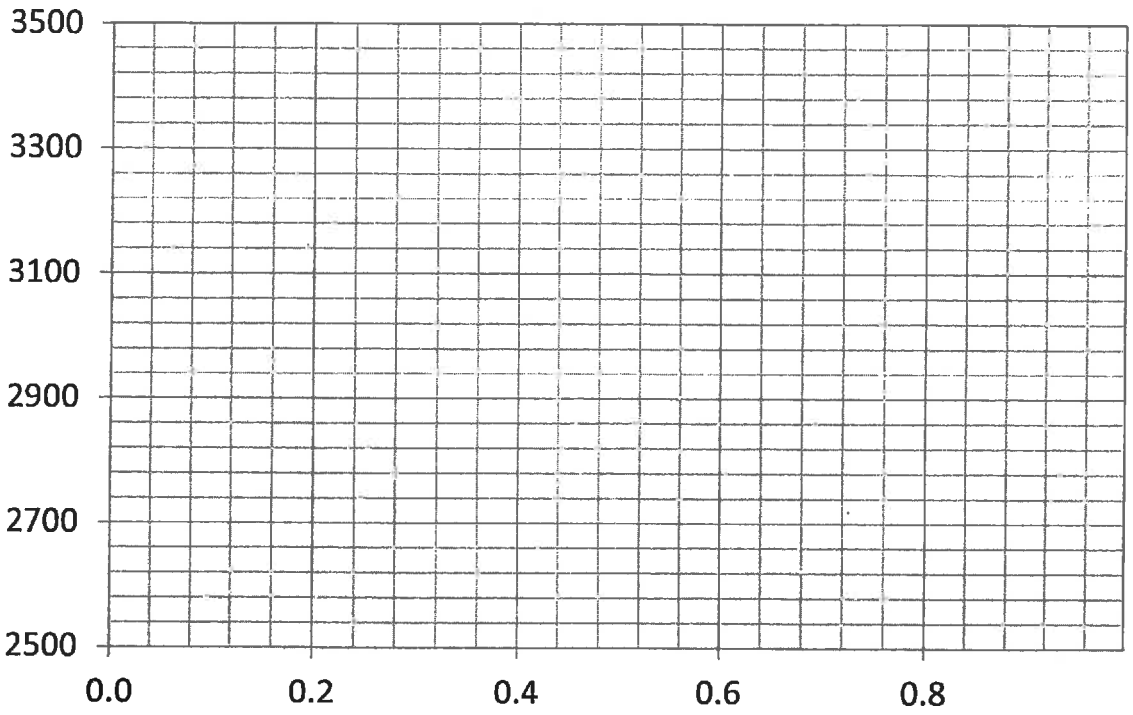
Question 6 (20 Marks)

Pressure and derivative plots for a drawdown test in a hydraulically fractured well are show in the following. Given the reservoir and fluid properties estimate fracture half-length and skin factor for this oil well. Assume an infinite conductivity hydraulic fracture. Required plots and chart are given in the following.

Oil rate, $q = 200$ STBD,
Reservoir permeability, k=1.95 mD,
Formation thickness, $h = 12$ ft,
Oil formation volume factor, $B_o = 1.325$ bbl/STB,
Initial pressure, $p_i = 3343.40$ psia
Porosity, ϕ= 11.8%,
Total compressibility, $c_t = 14.7 \times 10^{-6}$ psi^{-1}
Wellbore radius, $r_w = 0.25$ ft
Oil viscosity, $\mu_o = 0.49$ cP.

Time (hours)	p_{wf} (psia)
0.0000	3343
0.0010	3314
0.0040	3292
0.0090	3269
0.0128	3257
0.0239	3228
0.0320	3211
0.0426	3192
0.0564	3172

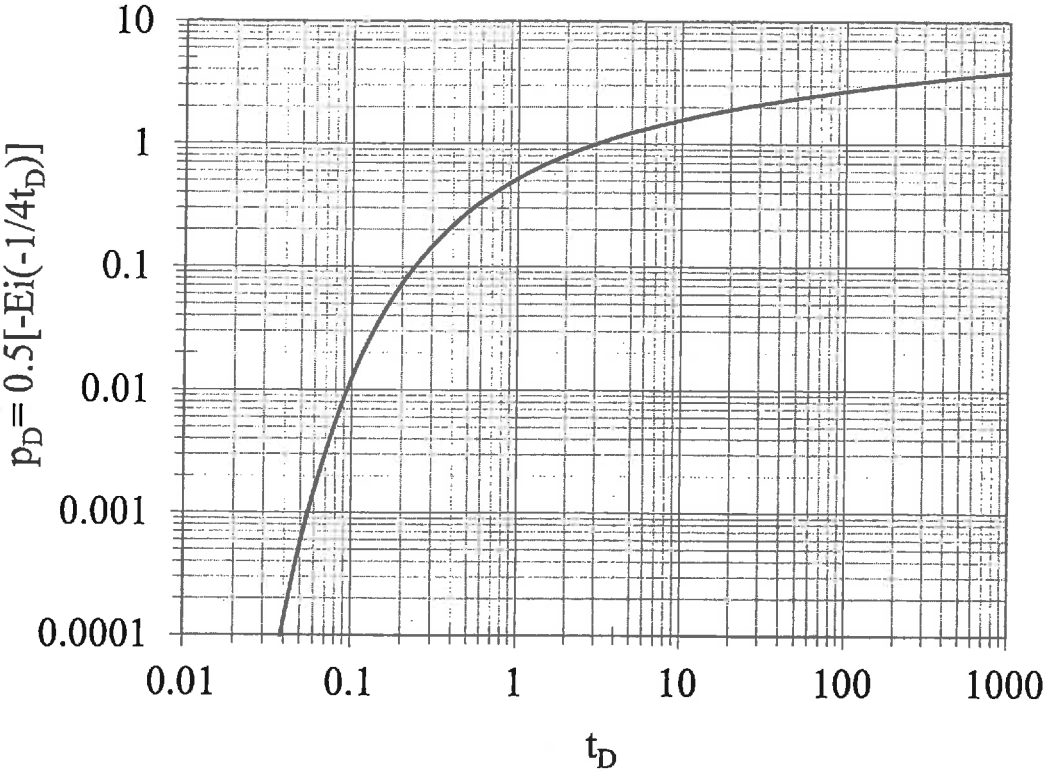




Question 7 (20 Marks)

A two-rate flow test has been conducted on a recently completed well in an undersaturated oil infinite acting reservoir. The well is produced at 25 STBD for 24 hours. The rate is then increased to 50 STBD for 72 hours. A flowing bottom hole wellbore pressure of 1000 psia has been recorded at the end of the second flow period (i.e., total test period of 96 hours).
The test was interpreted by a fellow reservoir engineer and a formation permeability of 162.6 mD and a skin factor of 2 have been estimated. Calculate the initial reservoir pressure. Required plot for calculations is given in the following.

Formation thickness, $h = 50$ ft,
Oil formation volume factor, $B_o = 1.143$ bbl/STB,
Porosity, $\phi = 0.082$,
Total compressibility, $c_t = 10.5 \times 10^{-6}$ psi^{-1},
Oil viscosity, $\mu_o = 1.278$ cp,
Wellbore radius, $r_w = 0.45$ ft.



Plot of dimensionless pressure versus dimensionless time

Formula Sheet

Slope of semi-log straight line, psi/cycle: $m = \dfrac{162.6q\mu B_o}{kh}$

Radius of investigation. ft: $r \approx \sqrt{\dfrac{kt}{948\phi\mu c_t}}$

Permeability-thickness product for double porosity reservoirs, mD-ft $(kh)_f = \hat{k}_f h = \dfrac{162.6q\mu B}{m}$

Average fracture permeability, mD $\hat{k}_f = \hat{k}_f h / h$

Skin factor for buildup test: $S = 1.151\left(\dfrac{p(1hr) - p_{wf}(\Delta t = 0)}{|m|} - \log\left(\dfrac{k}{\phi\mu c_t r_w^2}\right) + 3.23\right)$

Skin factor for drawdown test: $S = 1.151\left(\dfrac{p_i - p(1hr)}{|m|} - \log\left(\dfrac{k}{\phi\mu c r_w^2}\right) + 3.23\right)$

Pseudo steady state equations: $\dfrac{dp_w}{dt} = -\dfrac{0.234qB_o}{c_t V_P}$, (psi/hr)

$$p(r_w, t) = p_i - \frac{0.0744qB_o t}{\phi c_t h r_e^2} + \frac{q\mu B_o}{0.00708kh}\left[\ln\left(\frac{r_e}{r_w}\right) - \frac{3}{4} + S\right]$$

Horner time ratio: $\dfrac{t_p + \Delta t}{\Delta t}$

Distance to fault, ft: $L = \sqrt{\dfrac{0.000148k\Delta t}{\phi\mu c_t}}$

The approximate time required for the slope to double, hr $\Delta t = \dfrac{3.8\times10^5\phi\mu c_t L^2}{k}$

$$p(r,t) = p_i - \frac{q\mu B_o}{0.00708kh} p_D, \qquad \eta = \frac{0.0002637k}{\phi\mu c_t}, \qquad t_D = \frac{\eta t}{r^2}$$

$p_D = \dfrac{1}{2}(\ln t_D + 0.809)$ only if $t_D > 100$, for $t_D < 100$ use the provide p_D graph.

$$p(r,t) = p_i - \frac{0.141q\mu B_o}{kh}(p_D + S)$$

Gas wells build up

$$m = \frac{1637q_g T}{kh}$$

$$S' = 1.151\left(\left(\frac{p_{1hr} - p_{pwf}(@\Delta t = 0)}{m}\right) - \log\left(\frac{k}{\phi\mu c_t r_w^2}\right) + 3.23\right)$$

Fracture half length

$$L_f = \frac{4.064qB_o}{mh\sqrt{k}}\left(\frac{\mu_o}{\phi c_t}\right)^{0.5}, \quad L_f = 2r_{we}^{-S}$$

Nomenclature

B_o	Oil formation volume factor	bbl/STB
c_t	Total compressibility	1/psi
h	Formation thickness	ft
k	Permeability	mD
L	Distance	ft
p	Pressure	psia
p_p	Pseudo pressure	$psia^2/cP$
q	Oil flow rate	STBD
q_g	Gas flow rate	MSCFD
r	Radius	ft
S	Skin factor	dimensionless
T	Temperature	Rankin
t	Time	hr
V_P	Pore volume	ft^3
ϕ	Porosity	fraction
μ	Oil viscosity	cP
η	Hydraulic diffusivity	ft^2/hr

Subscripts

D	dimensionless
e	external
f	fracture
i	initial
o	oil
p	production
t	total
w	wellbore

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