Key

PETE 324

Exam A

February 14, 2005

50 minutes, closed book except for 1 cheat sheet, calculator, and straight edge. Turn in you cheat sheet with your exam. Show your work. Include the units. Use symbols instead of values when necessary.

1. **(15 points)** Write the defining equations for dimensionless pressure and time for the standard radial model. Indicate the units of each of the variables.

$$p_D = \frac{k h (p_i - p_{wf})}{141.2\, q B \mu}$$

md, ft, psi; q: STB/D; B: RB/STB; μ: cp

$$t_D = \frac{0.00633\, k t}{\phi \mu c_t r_w^2}$$

t: days; φ: fraction; c_t: psi^{-1}; r_w: ft

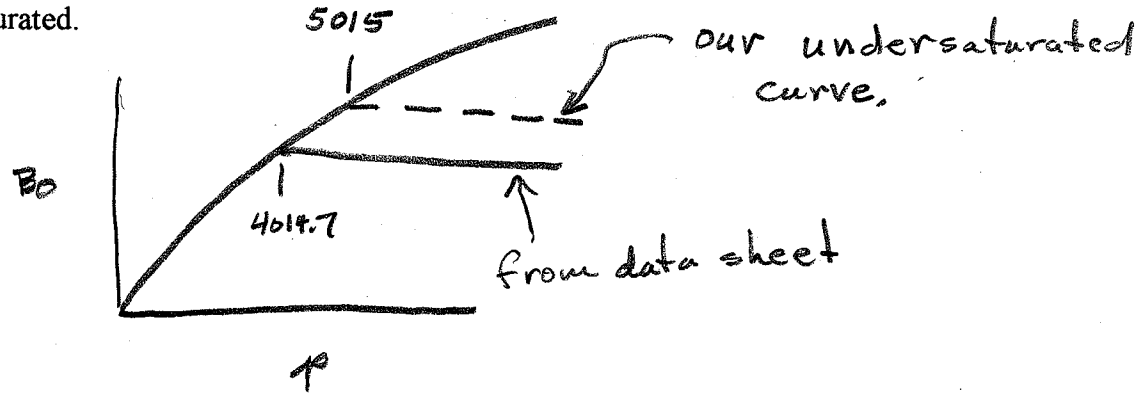
[or, use 0.000264 w/ hours]

each unit or const. −2

each eqn −5

r_w^2 −2

2. (15 points) Attached is the PVT data for the SPE1 test case. Calculate c_o at 5,015 psi, assuming that
(a) the oil is saturated.
(b) the oil is undersaturated.



(a) saturated

$$c_o = -\frac{1}{B_o}\frac{\Delta B_o}{\Delta p} + \frac{B_g}{B_o}\frac{\Delta R_s}{\Delta p} = \frac{-1}{1.8270}\frac{(2.357-1.8270)}{(9014.7-5014.7)} + \frac{0.000649}{1.8270}\frac{(2984.0-1618.0)}{(4000)}$$

$$= [-53.3 + 121.2]\times 10^{-6} = \boxed{48.9 \times 10^{-6}\ psi^{-1}}$$

slope from undersaturated data

(b) undersaturated

$$c_o = -\frac{1}{B_o}\frac{\Delta B_o}{\Delta p} = -\frac{1}{1.8270}\frac{(1.5790-1.6950)}{(9014.7-4014.7)}$$

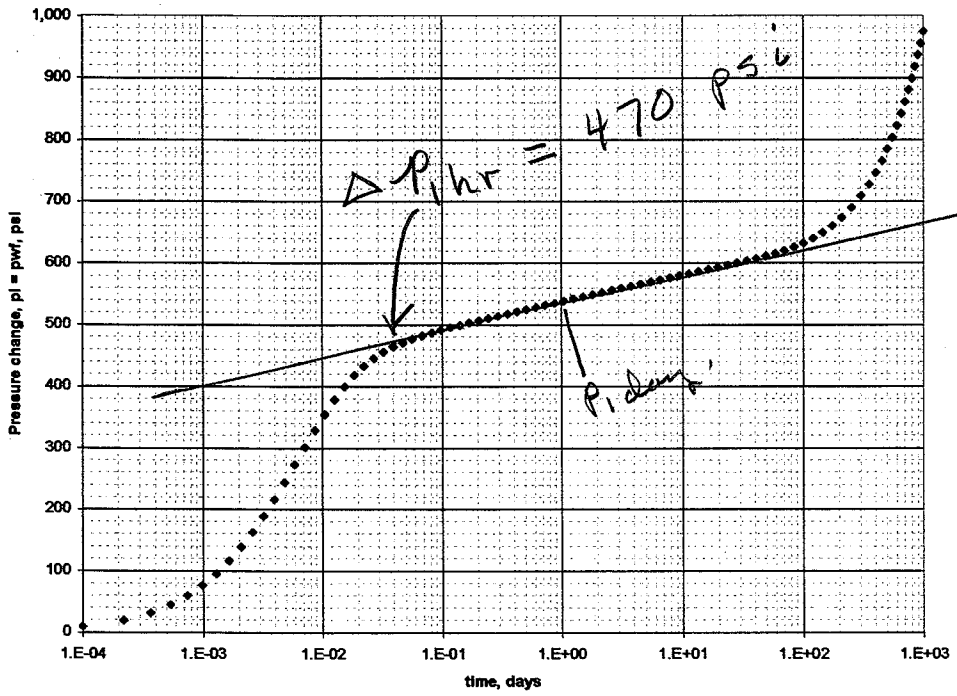
$$= \boxed{12.7 \times 10^{-6}\ psi^{-1}}$$

(a) B_o $^{-2}$ B_g $^{-2}$ $\left(\frac{\Delta B_o}{\Delta p}, \frac{\Delta R_s}{\Delta p}\right)$ $^{-2}$ formula $^{-5}$ arith $^{-2}$

(b) B_o $^{-2}$ $\frac{\Delta B_o}{\Delta p}$ $^{-2}$ formula $^{-5}$ arith $^{-2}$

3. (20 points) A "drawdown" flow test is conducted with a well flowing at constant rate. The plot of $(p_i - p_{wf})$ vs. t is attached. Calculate k and s from this plot, given the following data:

$p_i = 3{,}091$ psia	$\mu = 0.70$ cp	$h = 110$ ft
$q = 221$ stb/d	$\phi = 0.19$	$r_w = 0.25$ ft
$B = 1.15$ rb/stb	$c_t = 24.3 \times 10^{-6}$ psi^{-1}	$S_w = 0.21$



$$k = \frac{162.6\, q B \mu}{m h} = \frac{162.6\,(221)(1.15)(0.7)}{(40)(110)}$$

$$= \boxed{6.57 \text{ md}}$$

$$s = 1.151 \left[\frac{p_i - p_{1hr}}{m} - \log \frac{k}{\phi \mu c_t r_w^2} + 3.23 \right]$$

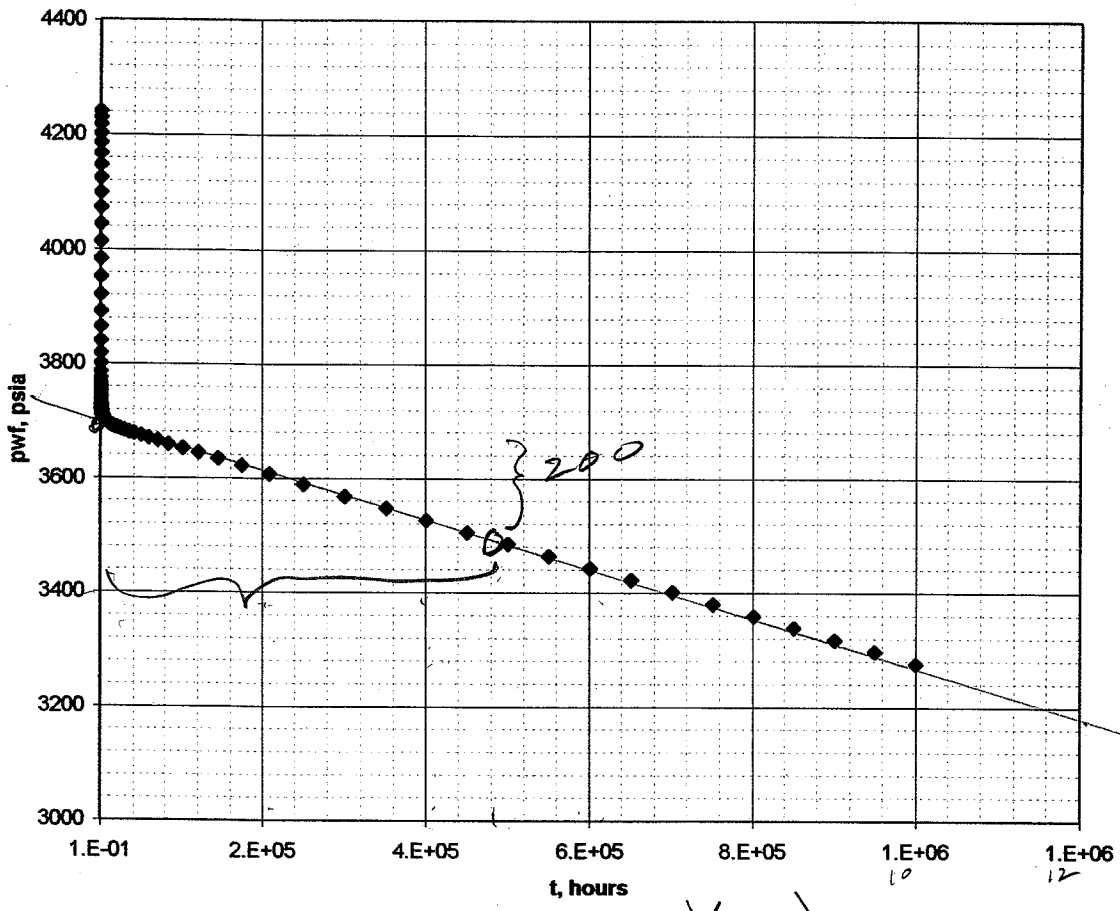
$$= 1.151 \left[\frac{(470)}{(40)} - \log \frac{(6.57)}{(0.19)(0.7)(24.3\times10^{-6})(0.25)} + 3.23 \right]$$

$$= 1.151 \left[11.75 - 7.51 + 3.23 \right]$$

$$= \boxed{8.6}$$

m → 5
k formula → 5
Δp,hr → 5
s formula → 5

4. (15 points) Calculate (a) pore volume and (b) oil-in-place from the following graph. Use the following data: $c_t = 35 \times 10^{-6}$ psi-1, $r_e = 900$ ft, $h = 24$ ft, $B_o = 1.15$ rb/stb, $q_o = 125$ stb/d, $\varphi = 0.18$.



slope = $\frac{200 \text{ psi}}{4.8 \times 10^5 \text{ hrs}}$

$= 0.000417 \text{ psi/hr}$

$= \boxed{0.01 \text{ psi/D}}$

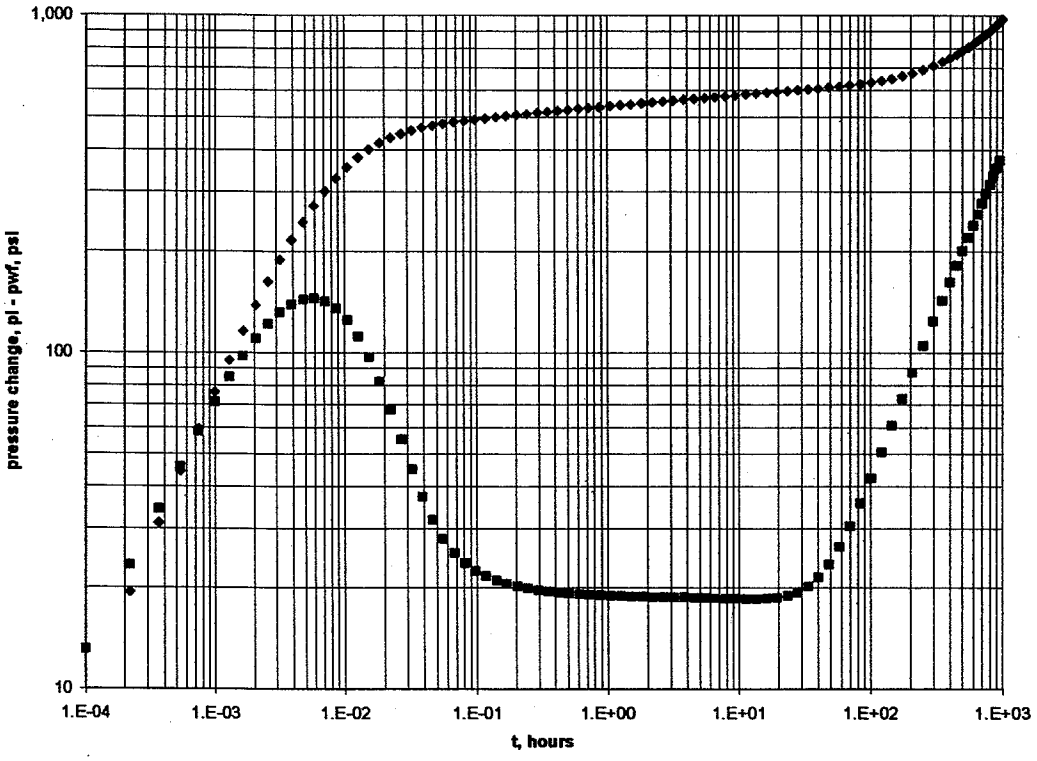
(a) $\frac{dp}{dt} = \frac{-qB}{V_p c_t} = \frac{-(125)(1.15)}{V_p (35 \times 10^{-6})} = -0.01$

$V_p = \boxed{410. \times 10^6 \text{ RB}}$

(b) $OOIP = \frac{V_p (1 - S_w)}{B_o}$ Assume $S_w = 0.20$, for example

$= \frac{410 \times 10^6 (1 - 0.20)}{(1.15)} = \boxed{285 \times 10^6 \text{ STB}}$

5. (15 points) Suppose you have the following log-log plot of field data. Attached is the corresponding type curve for a radial well with WBS & S. Calculate the skin factor, s, assuming that $C_D = 1{,}000$.



"height" of WBS & S hump $= \frac{150}{19} = 7.895$

Now, find the same ratio on the type curve,

We know that the derivative curve is 0.5 for SLSL, so

$$\frac{(p_D)_{peak}}{0.5} = 7.895$$

$$(p_D)_{peak} = \boxed{3.95}$$

Read $C_D e^{2s} = 10^8$ (the 10th curve down)

$$(1000)e^{2s} = 10^8$$

$$2s = \ln(10^5) = 11.5 \quad ; \quad s = \boxed{5.76}$$

6. (20 points) An input data sheet from Gassim is attached (this is not the data used for HW problem no. 3). [Note that $c_o = 0$ when CNST is used].

(a) Calculate the rate of pressure change (psi/day) of the very, very early rate of pressure change during the WBS period

(b) Calculate the skin factor, s.

(a)

$$\frac{dp}{dt} = \frac{-qB}{V_{WB}\, c_t} = \frac{-(720\ \frac{scf}{D})(1.2\ \frac{rcf}{scf})}{(36.5.2)(15.6\times 10^{-6})}$$

$$V_{WB} = \pi(0.25^2 - 0.001^2)(150)(12.4)$$

$$c_t = c_f + c_o s_o + c_w s_w$$
$$= [15.0 + 0 + (3.0)(0.20)]\times 10^{-6}$$
$$= 15.6\times 10^{-6}\ psi^{-1}$$

$$\frac{dp}{dt} = 0.152\times 10^{6}\ psi/D$$
$$= \boxed{152{,}000\ psi/D}$$

(b) $$s = \left(\frac{k}{k} - 1\right)\ln\frac{r_s}{r_w}$$
$$= \left(\frac{12}{0.2} - 1\right)\ln\frac{(0.5564)}{(0.25)}$$
$$= \boxed{47.2}$$

or, $r_s = 1.8477$, $s = 118$ (because of confusing comment)

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CASE  EXAM A
CMNT  Homogeneous Cylindrical Reservoir
CMNT  Radial      Flow, Constant-rate     production, Infinite-acting

CMNT  Slightly    Compressible      Fluid
CMNT
CMNT  Wellbore    is    modeled     by    the   first cell  to    show
CMNT  Single      Value Input Data
IMAX  30
JMAX  1
RWEL  0.001
CROC  0.000015
SWAT  0.2
CWAT  0.000003
PREF  3000
NEWT  1
BETA  0
CMNT  Bo,    rcf/scf     viscosity   cp
CNST  1.2    0.82
END
CMNT  Grid  Input Data
CMNT  Geometrically     spaced      grid  system
CMNT  b     =     1.49
CMNT  The   actual      value of    rw    is    assigned    to    the
RR -1               1.491895506
   0.25     0.372973876 0.55643805 0.830147426 1.238493214 1.847702459 2.756578994
      4.112527812 6.13546176
   13.65601751    20.37335114 30.394911   45.34603112 67.65154003 100.9290285
      150.575564  224.6430072 335.1438928
   550      600   650   700   750   800   850   900   950
DELY  150
KX  12
KY  12
PHI   0.23
POI   3000
CMNT  Gridblock 1 is for wellbore storage

WIND  1     1     1     1
PHIS  12.4
KX 1000000
KY 1000000
CMNT  Gridblocks 2 through 6 have a reduced permeability, representing well damage

WIND  2     3     1     1
KX  0.2
KY  0.2
END
CMNT  Schedule    Data
CMNT  Well  No.   i     -     location    j     -     location    skin
NAME  1     1     1     0
CMNT  Well  No.   scf/D
QG 1  720.0
ALPH  1.2
DELT  0.0001
DTMX  50
WELL  1
PMAP  2
TIME  1000
END
```

15×10^{-6}

$V_{WB} = \pi (0.25^2 - 0.001^2)(150)(12.4)$

$= 36.52\ ft^3$

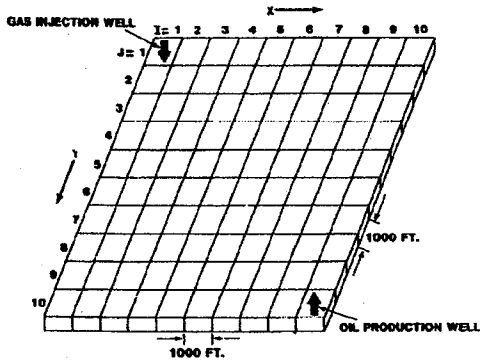


Fig. 1 – Reservoir and grid system.

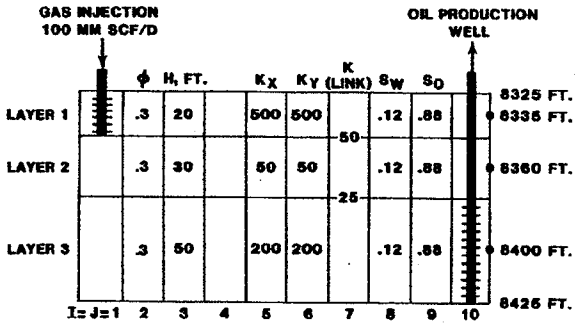


Fig. 2 – Diagonal cross section.

TABLE 1 – DATA AND CONSTRAINTS

Initial reservoir pressure, psia at 8,400 ft	4,800
Gas injection rate, MMscf/D	100
Maximum oil production rate, STB/D	20,000
Minimum oil rate, STB/D	1,000
Minimum flowing bottomhole pressure, psi	1,000
Maximum saturation change during time step	0.05
Rock compressibility, 1/psi	3×10^{-6}
Porosity value of 0.3 was measured at a base pressure of 14.7 psi	
Wellbore radius, ft	0.25
Skin	0
Capillary pressure	0
Reservoir temperature, &F	200
Gas specific gravity	0.792
Runs are terminated either at the end of 10 years or when GOR≤20,000 scf/STB or when the oil production rate≤1,000 STB/D; whichever occurs first terminates the run.	

TABLE 2 – PVT PROPERTIES

Saturated Oil PVT Functions

Reservoir Pressure (psia)	FVF (RB/STB)	Viscosity (cp)	Density (lbm/cu ft)	Solution GOR (scf/stb)
14.7	1.0620	1.0400	46.244	1.0
264.7	1.1500	0.9750	43.544	90.5
514.7	1.2070	0.9100	42.287	180.0
1014.7	1.2950	0.8300	41.004	371.0
2014.7	1.4350	0.6950	38.995	636.0
2514.7	1.5000	0.6410	38.304	775.0
3014.7	1.5650	0.5940	37.781	930.0
4014.7	1.6950	0.5100	37.046	1270.0
5014.7	1.8270	0.4490	36.424	1618.0
9014.7	2.3570	0.2030	34.482	2984.0

Saturated Water PVT Functions

Reservoir Pressure (psia)	FVF (RB/bbl)	Viscosity (cp)	Density (lbm/cu ft)	Gas/Water Ratio (scf/bbl)
14.7	1.0410	0.3100	62.238	0.0
264.7	1.0403	0.3100	62.283	0.0
514.7	1.0395	0.3100	62.328	0.0
1014.7	1.0380	0.3100	62.418	0.0
2014.7	1.0350	0.3100	62.599	0.0
2514.7	1.0335	0.3100	62.690	0.0
3014.7	1.0320	0.3100	62.781	0.0
4014.7	1.0290	0.3100	62.964	0.0
5014.7	1.0258	0.3100	63.160	0.0
9014.7	1.0130	0.3100	63.959	0.0

Undersaturated Oil PVT Functions

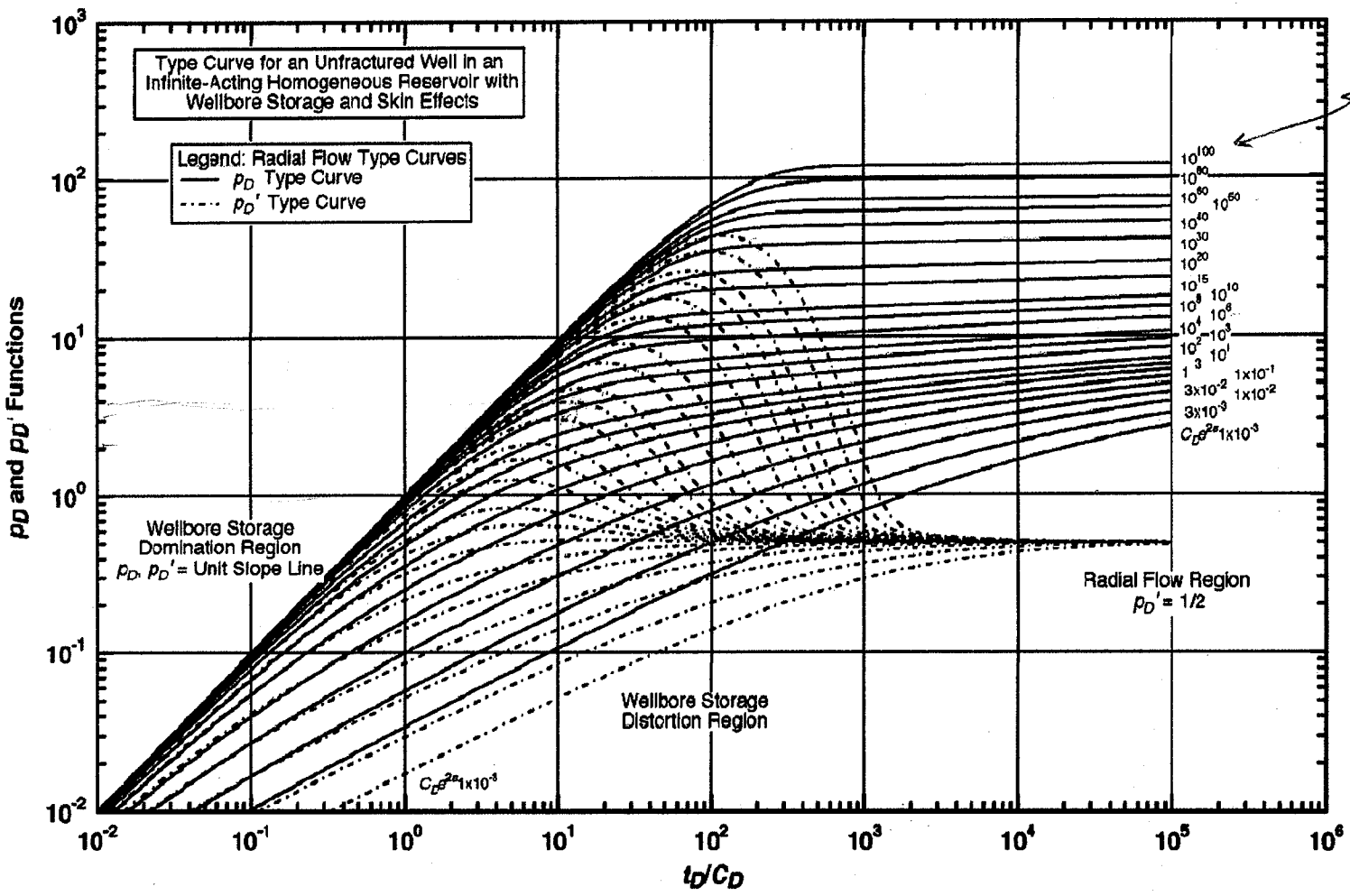
Reservoir Pressure (psia)	FVF (RB/STB)	Viscosity (cp)	Density (lbm/cu ft)
4014.7	1.6950	0.5100	37.046
9014.7	1.5790	0.7400	39.768

Undersaturated Water PVT Functions

Reservoir Pressure (psia)	FVF (RB/bbl)	Viscosity (cp)	Density (lbm/cu ft)
4014.7	1.0290	0.3100	62.964
9014.7	1.0130	0.3100	63.959

Gas PVT Functions

Reservoir Pressure (psia)	FVF (RB/scf) ~~(RB/bbl)~~	Viscosity (cp)	Density (lbm/cu ft)	Pseudo Gas Potential $M(p)$ (psia²/cp)
14.7	0.166666	0.008000	0.0647	0.
264.7	0.012093	0.009600	0.8916	0.777916 E+07
514.7	0.006274	0.011200	1.7185	0.267580 E+08
1014.7	0.003197	0.014000	3.3727	0.875262 E+08
2014.7	0.001614	0.018900	6.6806	0.270709 E+09
2514.7	0.001294	0.020800	8.3326	0.386910 E+09
3014.7	0.001080	0.022800	9.9837	0.516118 E+09
4014.7	0.000811	0.026800	13.2952	0.803963 E+09
5014.7	0.000649	0.030900	16.6139	0.112256 E+10
9014.7	0.000386	0.047000	27.9483	0.251845 E+10


Type Curve for an Unfractured Well in an Infinite-Acting Homogeneous Reservoir with Wellbore Storage and Skin Effects
Legend: Radial Flow Type Curves
p_D Type Curve
p_D' Type Curve
p_D and p_D' Functions
t_D/C_D
Wellbore Storage Domination Region
p_D, p_D' = Unit Slope Line
Wellbore Storage Distortion Region
Radial Flow Region
p_D' = 1/2
C_De^{2s}1x10^{-3}
C_De^{2s}
exponents
100
80
60
50
40
30
20
15
10
9
8
6
4
3
2
1
[3 x 10^0]
-1
-2
-2
-3
-3