Universitetet
i Stavanger

FACULTY OF
SCIENCE
AND TECHNOLOGY

FINAL EXAM: PET 670 Formation Evaluation and Well Testing

DATE: December 9, 2017

DURATION: 4 hours

"TOOLS" ALLOWED: Standard simple calculator (HP30S, Casio FX-82, TI-30 or Citizen SR-270X)

THE SET CONSISTS OF: PART A (2 problems 5p) and PART B (6 p)

Well Testing: Problem 1 (18 pts)

With data from a 48 hours buildup in a newly fractured well following just 30 minutes production at 300 STB/D, use parameters from Table 1, buildup data from Table 2 and Fig. 1 to answer the questions and carry out the analyses below.

a) Fig. 1 shows a log-log plot of the buildup data. Identify flow regimes in the data and indicate the range of each (start and end). (3 pts)

b) With Fig. 1 as reference, carry out a standard semi-log analysis of the buildup data based on representative data points from Table 2 to compute m, kh, k, Δp_{1hr}, S and Δp_S. (6 pts)

c) With Fig. 1 as reference and permeability from the previous point, use representative data points from Table 2 to determine the fracture half-length. Compared to the skin value, what is the likely fracture type? (3 pts)

d) Based on the buildup data, estimate the minimal area consistent with the pressure response. (3 pts)

e) Use semi-log analysis to estimate the formation pressure. Also, derive an estimate of the drawdown after 48.5 hours if the well had continued to produce at the initial rate without being shut in. (3 pts)

[-0,5]

-6078

886,62

6,4

13. Use the resistivity log to distinguish between the water-saturated and the hydrocarbon-saturated zones. Show these zones on the log. *(3 p.)*
Define the concept of net sand (net-to-gross ratio). *(1 p.)*
Calculate the net sand for the porous, permeable zone shown in the log. *(1 p.)*

14. Use the neutron porosity / bulk density log to divide the hydrocarbon-saturated zone into gas and oil zones. Show these zones on the log and identify the fluid contacts. *(5 p.)*

15. Mark the shale base line on the SP log. *(1 p.)*
— Is the formation fluid more or less saline than the mud filtrate? Why? *(2 p.)*
— Does the log likely come from an offshore well? Why? *(2 p.)*

16. Read off density and apparent porosity from the neutron porosity / bulk density log in the oil-saturated zone. *(2 p.)*
Use the crossplot in Fig.2 to estimate the porosity of this zone and identify its lithology. *(3 p.)*

17. Calculate the porosity of the porous and permeable zone based on the resistivity measurements. Explain your procedure and indicate which formulas and log readings you are implementing. *(5 p.)*

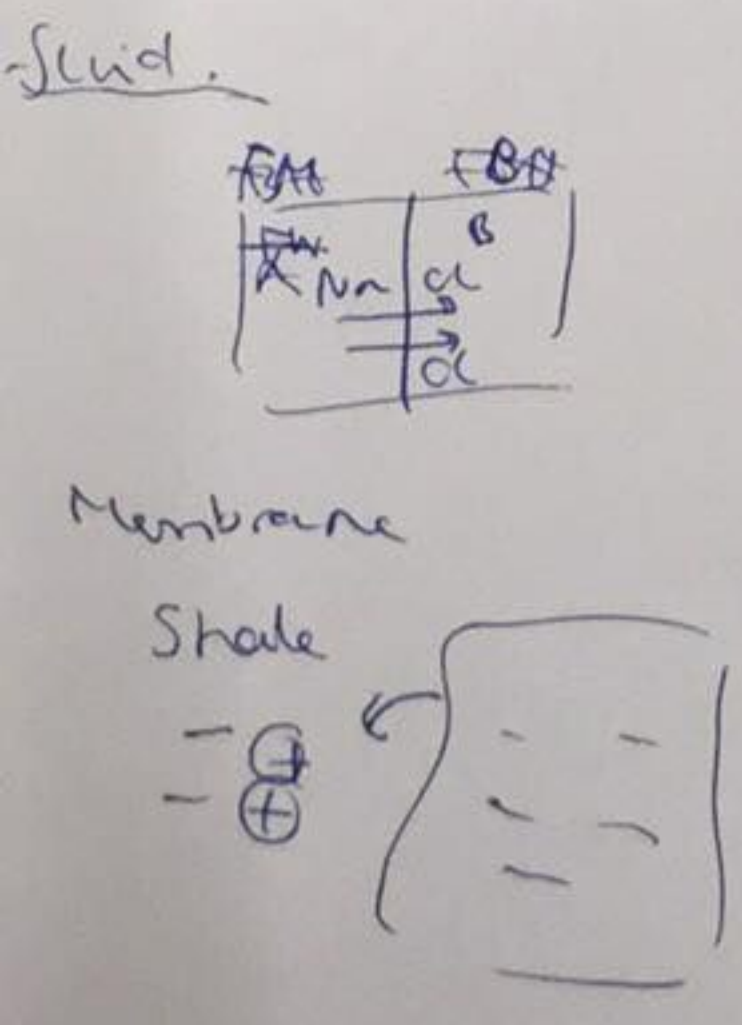
18. Calculate the residual water saturation, the residual hydrocarbon saturation, and the moveable hydrocarbon saturation. Explain your procedure and indicate which formulas and log readings you are implementing. *(5 p.)*

To answer Questions 19 and 20, interpret the pressure log shown in Fig.3. Make necessary marks directly on the figure sheet and hand in this sheet together with the rest of your answers.

The interval shown in Fig.3 is mainly pure sand, but shale layers (ca 0.5 m) have been identified at the following depths: 1040 m; 1060 m; 1090 m; 1120 m.

19. Calculate all relevant hydrostatic pressure gradients. *(2 p.)*
Estimate the fluid densities in different intervals. *(2 p.)*
Where is the free water level? *(1 p.)*

20. The rock has an entry pressure of 0.5 bar.
Specify the depth at which the oil-water contact is located. *(3 p.)*
Which zones are likely to be connected? Explain. *(2 p.)*



5. What is the principle of caliper logging? *(1 p.)*
Explain the term "on gauge". *(1 p.)*
How does the caliper respond to permeable formations? *(1 p.)*
How can the caliper be used to estimate the well volume? *(2 p.)*

6. Name the chemical elements which are the main sources of natural radioactivity in rocks. *(3 p.)*
One of these elements (which one?) is much less radioactive than others, but its contribution is still essential. Why? *(2 p.)*

7. What is the principle of GR logging tool? Provide a very short answer. *(1 p.)*
How and why the total GR log readings are altered if:
   (a) A barite mud is used? *(2 p.)*
   (b) A KCl-containing mud is used? *(2 p.)*

8. The neutron logging tool emits high energy neutrons.
Mention two processes that affect the emitted neutrons in the formation. *(2 p.)*
How does clorine affect the neutron log, and how can this effect be avoided? *(2 p.)*
How does shale affect the neutron log? *(1 p.)*

9. How are two key rock properties affected by the presence of diagenetic chlorite clay in reservoir sandstones? *(2 p.)*
What is an evaporite? *(1 p.)*
Name two ways to identify evaporites. *(2 p.)*

10. Name three applications of the sonic log. *(3 p.)*
Formulate Archie's 1st and 2nd laws. *(2 p.)*

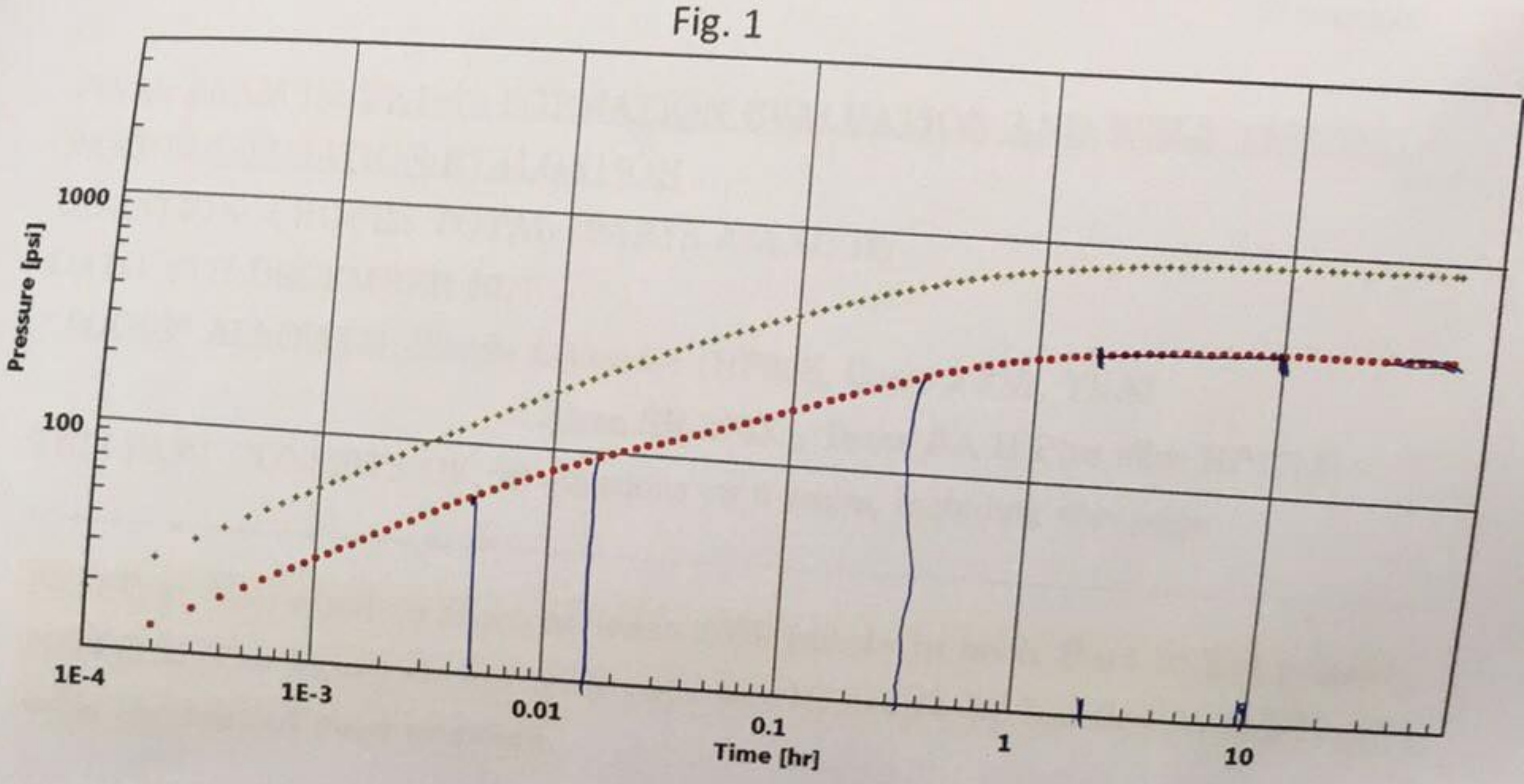
To answer Questions 11-18, interpret the well logs shown in Fig.1.
You will also use the crossplot in Fig.2 for Question 16.
Make necessary marks directly on the figure sheets
and hand in these sheets together with the rest of your answers.

The following information from laboratory is known:
Brine resistivity $R_w = 0.0077\,\text{Ohm·m}$
Mud filtrate resistivity $R_{mf} = 0.0051\,\text{Ohm·m}$
Cementation exponent $m = 2$
Saturation exponent $n = 2.5$

11. Mark the sand line and the shale line on the total GR log. *(2 p.)*
What are the corresponding values GR_{sh} and GR_{sand} in API units? *(2 p.)*
The GR log reading shows 80 API units in some shaly sand zone. Calculate the shale volume, V_{sh}, in this zone. *(1 p.)*

12. Mark the zones with positive and negative separation on the neutron porosity / bulk density log. *(2 p.)*
Identify the lithologies and show them in the Depth track. *(3 p.)*

Fig. 1



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FINAL EXAM IN: PET670 FORMATION EVALUATION AND WELL TESTING

PART B: FORMATION EVALUATION

DURATION: 4 HOURS TOTAL (PARTS A AND B)

DATO: 9TH DECEMBER 2017

"TOOLS" ALLOWED: Simple calculator (HP30S, Casio FX82, TI-30,
Citizen SR-270X , Texas BA II Plus eller HP17bII+

THIS PART CONSISTS OF: 20 questions on 6 pages, including this page.

NOTE 1: You need to score at least 40% points in each Part to get passed.
NOTE 2: The figure sheets with your marks are to be handed in together with the rest of your answers.

1. Define the following concepts: OOIP, STOOIP, formation volume factor. *(3 p.)*
   Is the formation volume factor for oil greater or less than 1? *(1 p.)*
   Give a short explanation why. *(1 p.)*

2. Here are three statements about measurements of porosity in laboratory:
   (a) Both saturation and buoyancy method measure the effective, or interconnected porosity, not the total porosity.
   (b) The porosity value measured by helium porosimetry is lower-than-actual.
   (c) By mercury porosimetry, one can measure both the effective porosity of the sample and the pore size distribution.

   Which of these statements are correct and which are not? *(3 p.)*
   Find the wrong statements and explain why they are wrong. *(2 p.)*

3. Describe (in a sentence each) two methods to measure capillary pressure in the lab. *(2 p.)*
   What is the relation between capillary pressure and saturation distributions in the reservoir? *(1 p.)*
   What is the difference between Free Water Level and Oil Water Contact? *(2 p.)*

4. What is invasion? *(1 p.)*
   Sketch a typical invasion profile when:
   (a) a water-based mud is used in a hydrocarbon formation; *(2 p.)*
   (b) an oil-based mud is used in a water formation. *(2 p.)*

Table 1 – Input parameters for Problem 1

Formation thickness, h	=	110	ft
Porosity, ϕ	=	0.09	
Viscosity, μ	=	0.85	cp
Total compressibility, c_t	=	7.7×10^{-6}	psi^{-1}
Volume factor, B	=	1.25	RB/STB
Wellbore radius, r_w	=	0.354	ft
Pressure at shut-in, $p_{wf,s}$	=	3778.53	psia

Table 2 – Buildup data

Buildup Time (hrs)	Pressure (psia)	Buildup Time (hrs)	Pressure (psia)	Buildup Time (hrs)	Pressure (psia)
0.0001	3796.55	0.0159	3990.10	1.2649	4555.33
0.0002	3803.98	0.0200	4011.80	1.5924	4576.20
0.0003	3809.66	0.0252	4034.96	2.0047	4594.22
0.0004	3814.44	0.0318	4059.56	2.5238	4609.61
0.0005	3818.79	0.0400	4085.60	3.1773	4622.55
0.0006	3823.66	0.0504	4113.06	4.0000	4633.34
0.0008	3829.11	0.0634	4141.95	5.0357	4642.26
0.0010	3835.21	0.0798	4172.22	6.3396	4649.58
0.0013	3842.04	0.1005	4203.85	7.9810	4655.55
0.0016	3849.67	0.1265	4236.75	10.0475	4660.39
0.0020	3858.21	0.1592	4270.76	12.6491	4664.31
0.0025	3867.76	0.2005	4305.62	15.9243	4667.46
0.0032	3878.40	0.2524	4340.94	20.0475	4669.99
0.0040	3890.25	0.3177	4376.21	25.2383	4672.02
0.0050	3903.38	0.4000	4410.83	31.4783	4673.58
0.0063	3917.86	0.5036	4444.20	37.7183	4674.63
0.0080	3933.75	0.6340	4475.72	43.9583	4675.39
0.0100	3951.08	0.7981	4504.98	48.0000	4675.77
0.0126	3969.86	1.0048	4531.67		

Well Testing: Problem 2 (12 pts)

The following data were recorded from a deliverability test of a new gas well.

Elapsed time (hr)	p_{wf} (psia)	q_{sc} (Mscf/d)
0	7952	0
12	7750	2786
24	7934	0
36	7635	3910
48	7919	0
60	7445	5592
72	7901	0
84	7259	6985
216	7150	6706

7952.
?

a) Based on the listed data, what type of test is this (flow-after-flow, isochronal or modified isochronal)? Which pressure formulation is most correct for this data set (p or p^2)? (2 pts)

b) Determine the deliverability and AOF potential of the well by using LIT analysis and direct computations. (5 pts)

c) Determine the deliverability and AOF potential of the well by using simple log-log analysis (back-pressure equation) and direct computations. (5 pts)

d) Assuming that the b term from LIT analysis is independent of permeability, how will the deliverability based on LIT analysis change if the permeability is reduced by a factor of 2? Use the new LIT results to update the parameters of simple log-log analysis (C&n analysis). (5 pts)

STANDARD EQUATIONS WELL TESTING

$$p_D = \frac{kh}{18.66qB\mu}\Delta p$$ (SI units, oil; field units: 18.66 → 141.2)

$$t_D = \frac{0.000355kt}{\phi\mu c_t r_w^2}$$ (SI units, oil and gas; field units: 0.000355 → 0.000264)

$$C_D = \frac{C}{2\pi\phi h c_t r_w^2}$$ (SI units, oil and gas; field units: $C \rightarrow 5.615C$)

$$C = \frac{qB}{24}\frac{t}{\Delta p} = c_{wb}V_{wb}$$

$$\Delta p = m't = \frac{qB}{24C}t$$

$$m = \frac{21.49qB\mu}{kh}$$ (SI units; field units: 21.49 → 162.6)

$$S = 1.151\left(\frac{p_i - p_{1hr}}{m} - \log\frac{k}{\phi\mu c_t r_w^2} + 3.098\right)$$ (SI units, DD data; field units: 3.098 → 3.227)

$$S = 1.151\left(\frac{p_{1hr} - p_{wf,s}}{m} - \log\frac{t}{t+1} - \log\frac{k}{\phi\mu c_t r_w^2} + 3.098\right)$$ (SI units, BU data)

?

$$\Delta p_S = \frac{m}{1.151}S$$

13.1x / 100 = m

$$r_{inv} = 0.0286\sqrt{\frac{kt}{\phi\mu c_t}}$$ (SI units; field units: 0.0286 → 0.0246)

$$d = 0.01412\sqrt{\frac{kt}{\phi\mu c_t}}$$ (SI units; field units: 0.01412 → 0.01217)

$$p_i - \overline{p} = \frac{m}{1.151} 2\pi t_{DA}$$

Fractured wells:

$$m' = \frac{0.6236qB}{hx_f}\sqrt{\frac{\mu}{k\phi c_t}}$$ (SI units; field units: 0.62369 → 4.064)

$$S = \ln\frac{2r_w}{x_f}$$ (fracture with infinite conductivity)

$$S = \ln\frac{er_w}{x_f} = \ln\frac{2.718r_w}{x_f}$$ (fracture with uniform flux)

Reservoir limit analysis:

$$m' = \frac{0.04167qB}{\phi c_t Ah}$$ (SI units; field units: 0.04167 → 0.2339)

$$p_0 = p_i - \frac{18.66qB\mu}{kh}\left(\frac{1}{2}\ln\frac{4A}{e^{\gamma}C_A r_w^2} + S\right)$$ (SI units; field units: 18.66 → 141.2)

$$e^{\gamma} = e^{0.57721\ldots} = 1.781\ldots$$

Gas tests:

$$q_{sc} = C(\overline{p}^2 - p_{wf}^2)^n$$ (simplified deliverability, p^2 formulation)

$$\overline{p}^2 - p_{wf}^2 = aq_{sc} + bq_{sc}^2$$ (LIT based deliverability, p^2 formulation)

$$\text{AOF} = \frac{1}{2b}\left(-a + \sqrt{a^2 + 4b\overline{p}^2}\right)$$ (LIT based AOF, p^2 formulation)