READ THIS PAGE CAREFULLY AND COMPLETELY BEFORE STARTING

Exam Submission: | Due date — Wednesday 09 August at 14:59:59 US CDT | Submit to — t-blasingame@tamu.edu |
- Return EXACTLY your completed exam (exactly 11 pages).
- File name: P663_17B_Exam_(ARP)_YOURLASTNAME.pdf
- Document: Single .pdf document
- Scan: >300 dpi COLOR scan from a printer/scanner
- Photos: DO NOT SUBMIT PHOTOS (will not be accepted)

Exam Requirements: (exam is open book/open notes) | Immediate Actions:
- Collaboration is expressly forbidden.
- Collaboration/cheating = F course grade.
- You have 2 (two) hours to complete the exam.
- (NOW!) Print the exam on a high resolution printer.
- (NOW!) Sign the Honor Code Statement.
- (NOW!) Write your name and sign every page on the exam.

Construction:
- Print the exam on (high-quality) blank white paper.
- HAND WRITE your work on the exam.
- ONLY WRITE ON THE FRONT OF THE PAGE!
- NO ELECTRONIC/TYPING PERMITTED.
- NO COMPUTER-AIDED WORK (e.g., MS Excel, etc.).
- NO INSERT OR EXTRA PAGES ARE ALLOWED!

Work Layout:
- NEATNESS: You will be graded on the neatness of your work.
- LABELS: All work, trends, and features on every plot MUST be appropriately labeled — no exceptions.
  — Work: All work must be fully labeled and documented — equations, relations, calculations, etc.
  — Trends: This includes the slope, intercept, and the information used to construct a given trend.
  — Features: Any description of features/points of interest on a given trend (times, pressures, etc.).
- LINES: Use appropriate drafting care in construction of lines, trends, arrows, etc.
- SKETCHING: Take great care in any sketches you create/use in your work.

Exam Problems:

(____/10 pts) 1. Log-Log Analysis — Pressure Buildup Test Analysis (WBS Domination and IARF)
(____/10 pts) 2. Cartesian Analysis — Early-Time Pressure Buildup Test Analysis (Wellbore Storage Domination)
(____/15 pts) 3. Semilog Analysis — Pressure Buildup Test Analysis (Infinite-Acting Radial Flow (IARF))
(____/10 pts) 4. Cartesian Analysis — Late Time Pressure Buildup Test Analysis ("Muskat-Arps-Smith" Method)
(____/15 pts) 5. log(Rate)-Time Analysis — Production Semilog Plot
(____/10 pts) 6. Rate-Cumulative Analysis — Reserves Estimation
(____/10 pts) 7. log(Rate)-Cumulative Analysis — Reserves Estimation
(____/10 pts) 8. Reciprocal Rate-Material Balance Time Reserves Estimation Plot
(____/10 pts) 9. Module Narrative

(____/100 pts) Total

Last Words:
- Neatness counts — more than you think. Keep your work complete and NEAT.
- Give your very best effort.
- You MUST show all work and clearly identify/label ALL features — NO EXCEPTIONS!
- Scholastic dishonesty — don't even think about it!

Aggie Code of Honor: An Aggie does not lie, cheat, or steal or tolerate those who do.

Required Academic Integrity Statement: (Texas A&M University Policy on Academic Integrity)
"On my honor, as an Aggie, I have neither given nor received unauthorized aid on this academic work."

______________________________  ______________________
(your printed name)  (your signature)
Introduction: (Information for ALL Problems)

This problem consists of a pressure buildup test performed on an oil well. The well is hydraulically fractured and is located in a symmetric, homogeneous reservoir of approximately 640 acres (i.e., 1 section).

Data: The relevant reservoir, fluid, and production properties are:

Reservoir and Fluid Properties:

- \( \phi = 0.05 \) (fraction)
- \( S_{wi} = 0 \) (fraction)
- \( r_w = 0.25 \) ft
- \( h = 100 \) ft
- \( p_i = 9,500 \) psia
- \( B_o = 1.25 \) RB/STB
- \( \mu_o = 0.8 \) cp
- \( c_i = 15 \times 10^{-6} \) psia\(^{-1}\)

Production Properties:

- \( q_o = 662 \) STB/D (final rate)
- \( t_p = 17,520 \) hr (730 D)
- \( p_{o\theta}(\Delta t=0) = 4338.37 \) psia (pressure at shut in)

Strip-Chart Summary Plot:
(10 pts) Problem 1: Log-Log Analysis — Pressure Buildup Test Analysis (WBS Domination and IARF)

Data: The relevant reservoir, fluid, and production properties are:

*Reservoir and Fluid Properties:*
- \( \phi = 0.05 \) (fraction)
- \( S_{wi} = 0 \) (fraction)
- \( r_w = 0.25 \text{ ft} \)
- \( h = 100 \text{ ft} \)
- \( p_i = 9,500 \text{ psia} \)
- \( B_o = 1.25 \text{ RB/STB} \)
- \( \mu_o = 0.8 \text{ cp} \)
- \( c_i = 15 \times 10^{-6} \text{ psia}^{-1} \)

*Production Properties:*
- \( q_o = 662 \text{ STB/D (final rate)} \)
- \( t_p = 17,520 \text{ hr (730 D)} \)
- \( p_w(\Delta t=0) = 4338.37 \text{ psia (pressure at shut in)} \)

**Required Results:** *(show/label all trends on plot)*
- Pressure drop at 1 hr on the log-log plot, \( \Delta p_{1hr, wbs} \)
- Pressure drop derivative for infinite-acting radial flow, \( \Delta p'_{IARF} \)
- Wellbore storage coefficient, \( C_s \)
- Estimation of permeability using log-log analysis

**Governing Relation(s):**

\[
\Delta p_{1hr, wbs} = \frac{qB}{24 C_s} \left[ C_s = \frac{qB}{24 \Delta p_{1hr, wbs}^2} \right] \\
m_{sl} = 162.6 \frac{qB \mu}{kh} \quad \text{note that} \quad m_{sl} = 2.303 \times \Delta p'_{IARF} \left[ k = 162.6 \frac{qB \mu}{h} \frac{1}{2.303 \times \Delta p'_{IARF}} \right]
\]

Work Space: *(Any/all work for this project must be documented on this page)*
Problem 2: Cartesian Analysis — Early-Time Pressure Buildup Test Analysis (Wellbore Storage Domination)

Data: The relevant reservoir, fluid, and production properties are:

- Reservoir and Fluid Properties:
  - $\phi = 0.05$ (fraction)
  - $S_{wi} = 0$ (fraction)
  - $r_w = 0.25$ ft
  - $h = 100$ ft
  - $p_i = 9,500$ psia
  - $B_o = 1.25$ RB/STB
  - $\mu_o = 0.8$ cp
  - $c_l = 15 \times 10^{-6}$ psia$^{-1}$

- Production Properties:
  - $q_o = 662$ STBOD (final rate)
  - $t_p = 17,520$ hr (730 D)
  - $p_w(\Delta t = 0) = 4338.37$ psia (pressure at shut in)

Required Results: (show/label all trends on plot)

- Pressure at shut-in time $= 0$, $p_w(\Delta t = 0)$
- Slope of the straight-line trend on the early-time Cartesian plot, $m_{wbs}$
- Wellbore storage coefficient, $C_s$

Governing Relation(s):

\[
p_{ws} = p_w(\Delta t = 0) + \frac{qB}{24C_s} t = p_w(\Delta t = 0) + m_{wbs} t
\]

\[
C_s = \frac{qB}{24m_{wbs}}
\]

Cartesian Plot (Early Time (Wellbore Storage Domination))

Work Space: (Any/all work for this project must be documented on this page)
(15 pts) Problem 3: Semilog Analysis — Pressure Buildup Test Analysis (Infinite-Acting Radial Flow (IARF))

**Data:** The relevant reservoir, fluid, and production properties are:

**Reservoir and Fluid Properties:**
- \( \phi = 0.05 \) (fraction)
- \( S_w = 0 \) (fraction)
- \( r_w = 0.25 \) ft
- \( h = 100 \) ft
- \( p_i = 9,500 \) psia
- \( B_o = 1.25 \) RB/STB
- \( \mu_o = 0.8 \) cp
- \( c_i = 15 \times 10^{-6} \) psia\(^{-1}\)

**Production Properties:**
- \( q_o = 662 \) STB/D (final rate)
- \( t_p = 17,520 \) hr (730 D)
- \( p_w(\Delta t=0) = 4338.37 \) psia (pressure at shut in)

**Required Results:** (show/label all trends on plot)
- Pressure at shut-in time = 1 hr, \( p_{w,i,1hr} \)
- Slope of the straight-line trend on the semilog plot, \( m_{sl} \)
- Formation permeability, \( k \)
- Pseudo-radial flow skin factor, \( s \) (dimensionless)

**Governing Relation(s):**

\[
m_{sl} = 162.6 \frac{q B_\mu}{k h} \left[ k = 162.6 \frac{q B_\mu}{h m_{sl}} \right]
\]

\[
s_{pr} = 1.513 \left[ \frac{(p_{w,i,1hr} - p_{w,f}(\Delta t = 0))}{m_{sl}} - \log \left( \frac{k}{\phi \mu c_i r_w^2} \right) \right] + 3.2275
\]

**Work Space:** (Any/all work for this project must be documented on this page)
(10 pts) Problem 4: Cartesian Analysis — Late Time Pressure Buildup Test Analysis ("Muskat-Arps-Smith" Method)

**Data:** The relevant reservoir, fluid, and production properties are:

- **Reservoir and Fluid Properties:**
  - \( \phi = 0.05 \) (fraction)
  - \( S_w = 0 \) (fraction)
  - \( r_w = 0.25 \) ft
  - \( h = 100 \) ft
  - \( p_i = 9,500 \) psia
  - \( B_o = 1.25 \) RB/STB
  - \( \mu_o = 0.8 \) cp
  - \( c_t = 15 \times 10^{-6} \) psia\(^{-1}\)

- **Production Properties:**
  - \( q_o = 662 \) STB/D (final rate)
  - \( t_p = 17,520 \) hr (730 D)
  - \( p_w(\Delta t=0) = 4338.37 \) psia (pressure at shut in)

**Required Results:** (show/label all trends on plot)

- Slope of the straight-line trend on the late-time Cartesian plot, \( m_{Arps} \)
- Average reservoir pressure, \( p_{avg} \)

**Governing Relation(s):**

\[
p_{ws} = \bar{p} - a \exp(-b\Delta t) \quad \Rightarrow \quad p_{ws} = \bar{p} - \frac{1}{b} \frac{d}{d\Delta t} [p_{ws}] = \bar{p} - m_{Arps} \frac{d}{d\Delta t} [p_{ws}] \text{ where } m_{Arps} = \frac{1}{b}
\]

[Cartesian Plot (Late Time (Average Reservoir Pressure)) [Arps-Smith Plot]]

**Work Space:** (Any/all work for this project must be documented on this page)
(15 pts) Problem 5: log(Rate)-Time Analysis — Production Semilog Plot

**Required Results:** (show/label all trends on plot)

- Estimate the intercept rate for the exponential time-rate relation \( q_{i,\text{exp}} \) = ___________ STB/D
- Estimate the decline constant for the exponential time-rate relation \( D_{i,\text{exp}} \) = ___________ 1/D
- Estimate the intercept rate for the hyperbolic time-rate relation \( q_{i,\text{hyp}} \) = ___________ STB/D
- Estimate the decline constant for the hyperbolic time-rate relation \( D_{i,\text{hyp}} \) = ___________ 1/D
- Estimate the hyperbolic parameter for the hyperbolic time-rate relation \( b \) = ___________ (dimensionless)

**Governing Relation(s):**

\[
q = q_{i,\text{exp}} \exp( -D_{i,\text{exp}} t ) \quad \text{(exponential decline relation)} \\
q = \frac{q_{i,\text{hyp}}}{(1 + b D_{i,\text{hyp}} t)^{1/b}} \quad \text{(hyperbolic decline relation)}.
\]

**Required:** You are to fit both the hyperbolic and exponential relations to the production data, and you must show all of work and construct your exponential and hyperbolic trends on the plot below.

**Work Space:** (Any/all work for this problem must be documented on this page)
(10 pts) Problem 6: Rate-Cumulative Analysis — Reserves Estimation

**Required Results:** (show/label all trends on plot)

Estimated Ultimate Recovery \((EUR \text{ or } N_{p,max})\) = ___________ STBO

**Governing Relation(s):**

\[ q_o = q_{ol} - D_i N_p \] (exponential rate-cumulative relation)

**Required:** You are to fit the exponential rate-cumulative relation to the production data, and you must construct your trend on the plot below.

![Rate-Cumulative Analysis — Production Semilog Plot](image)

**Workspace:** (Any/all work for this problem must be documented on this page)
(10 pts) Problem 7: log(Rate)-Cumulative Analysis — Reserves Estimation

Required Results: (show/label all trends on plot)

Estimated Ultimate Recovery ($EUR$ or $N_{P,max}$ at $q_{0,limit} = 100$ STBOD) = ___________ STBO

Governing Relation(s):

$$q = q_i \exp \left( \frac{D_i}{q_i} N_p \right)$$

(harmonic log(rate)-cumulative relation)

Required: You are to fit the harmonic log(rate)-cumulative relation to the production data, and you must construct your trend on the plot below. You are to extrapolate your trend to the limiting rate ($q_{0,limit} = 100$ STBOD).

Work Space: (Any/all work for this problem must be documented on this page)
Problem 8: Reciprocal Rate-Material Balance Time Reserves Estimation Plot

**Required Results:** *(show/label all trends on plot)*

Estimated Ultimate Recovery \((EUR \text{ or } N_{p,\text{max}})\) = ______________ STBO

**Governing Relation(s):**

\[
\frac{1}{q_o} = \frac{1}{q_{oi}} + \frac{D_t}{q_{oi}} \left[ \frac{N_p}{q_o} \right] = c + m \left[ \frac{N_p}{q_o} \right] \quad \text{(where } EUR = N_{p,\text{max}} = \frac{1}{m} \text{)}
\]

*(derived from the exponential rate-cumulative relation)*

**Required:** You are to fit the "reciprocal rate-material balance time" relation to the production data, and you must construct your trend on the plot below.

**Work Space:** *(Any/all work must be documented here)*
(10 pts) Problem 9: Module Narrative

**Required:** You are to write a narrative in the space below. The purpose of this narrative is to explain the elements that you have learned in this module. It is understood that this module presents an enormous about of information and that you have had relatively little time to immerse yourself in this material, but the goal is to assess your exposure — what you have learned, what you have understood, what you feel you have mastered. There are no "right" or "wrong" answers, but rather, just a desire to assess what you believe you have gained from this module. You are expected to provide a complete page of narrative/discussion specific to what you have reviewed and learned.
BEFORE YOU START

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