Self-Study Objectives: *Analysis of Reservoir Performance* [Blasingame]

Introduction to Reservoir Engineering:

- Be familiar with the World Oil Resources ................................................................. Slides — 3-4
- Be familiar with the Reservoir Structure/Depositional Environments ..................... Slide — 5
- Be familiar with Common Depositional Structures ................................................... Slide — 6
- Be familiar with the Concept of Porosity (packings of spheres) .............................. Slide — 7
- Be familiar with the Concept of Porosity (unconsolidated sands) ............................ Slide — 8
- Be familiar with the Concept of Permeability (Darcy’s Experiment) ....................... Slide — 9
- Be familiar with the Concept of Permeability — Definition of a “Darcy” .................. Slide — 10
- Be familiar with Petrophysics — Early Correlation Concepts .................................. Slide — 12
- Be familiar with Petrophysics — Introduction to Geology ....................................... Slide — 2
- Be familiar with Phase Behavior .............................................................................. Slides — 11-14
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- Be familiar with Formation Evaluation .................................................................. Slides — 15-17
  - Formation Evaluation (Types and Uses of Well Logs) .......................................... Slide — 15
  - Formation Evaluation — Formation Factor ($\phi$) .................................................. Slide — 16
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  - Reservoir Modeling — Perspectives ..................................................................... Slide — 24
  - Reservoir Modeling — General Concepts ............................................................. Slide — 25
  - Reservoir Modeling — Potential Areas of Conflict ............................................... Slide — 26
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- Be familiar with the History of Reservoir Engineering ......................................... Slides — 28-34
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  - History of Reservoir Engineering — Timelines ...................................................... Slide — 29
  - History — Tasks of the Reservoir Engineer ............................................................. Slide — 30
  - History — Data Sources/Reservoir Engineering Workflows ................................... Slide — 31
  - History — Fundamental Drive Mechanisms .......................................................... Slide — 32
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  - Geology — Basic Porosity Types — Sandstones ..................................................... Slide — 3
  - Geology — Sandstone Depositional Systems ...................................................... Slide — 4
  - Geology — Carbonate Depositional Systems — $\phi$ and $k$ ................................... Slide — 5
- Be familiar with Petrophysics ................................................................................. Slides — 6-7
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  - Petrophysics — Example — $k_{v,w}$, $k_{p,W}$ with $k_{v,n}$ mean .............................. Slide — 7
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  - Reservoir Petrophysics — $k = a \exp[b \phi]$ (Archie Trends) ............................ Slide — 18
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    - Phase Behavior — PT Diagram — Black Oil Reservoir Fluid ............................................................. Slide — 10
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- PVT Applications — PT Diagram (Black Oil) ............................................................................................ Slide — 32
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PVT Properties (Reservoir Fluids)

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- Material Balance — Historical Perspectives .......................................................................................... Slide — 3
- Material Balance — Petroleum Reservoirs .............................................................................................. Slide — 4
- Material Balance — Average Reservoir Pressure .................................................................................. Slide — 5
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- Material Balance — "Abnormal Pressure" Material Balance ..................................................................... Slide — 7
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- Material Balance — Volumetric Gas Reservoir Case .................................................................................. Slide — 9
- Material Balance — Abnormally-Pressured Gas Reservoir Case ............................................................... Slide — 10
- Material Balance — Water Influx Gas Reservoir Case ................................................................................ Slide — 11-12

**Pressure Transient Analysis:**

**Orientation — Pressure Transient Analysis:**
- Be familiar with the objectives of Pressure Transient Analysis ................................................................. Slide — 2-13
- Be familiar with the input data required for Pressure Transient Analysis ................................................... Slide — 2
- Be familiar with the results of Pressure Transient Analysis (PTA) interpretation ........................................ Slide — 2
- Be familiar with PTA diagnostic examples .............................................................................................. Slide — 3
- Be familiar with static data required for PTA (PVT, Reservoir Properties, Well Completion) .................. Slide — 4
- Be familiar with the issues related to production histories used for the analysis of pressure and rate data .... Slide — 5
- Be familiar with a tight gas example for PTA and Production Analysis .................................................... Slides — 6-7
- Be familiar with the production pressures and rates for a tight gas reservoir case ........................................ Slide — 6
- Be familiar with an example of PTA for a tight gas reservoir case ............................................................. Slide — 7
- Be familiar with the derivation of well deliverability (circa 1935) ............................................................... Slide — 8
- Be familiar with the concept of the "4-point" well deliverability test ......................................................... Slide — 9
- Be familiar with the layout of a typical reservoir/well/facilities system (after Fonseca) ............................. Slide — 10
- Be familiar with "next advances" expected in PTA and Production Analysis .............................................. Slide — 11-12
- Be familiar with the "Questions to Consider" for Pressure Transient Analysis (Orientation for PTA) .......... Slide — 13

**Basic Concepts/Processes — Pressure Transient Analysis:**
- Basic Concepts/Processes — Pressure Transient Analysis ........................................................................ Slides — 14-24
- Be familiar with tubular system schematics ............................................................................................. Slide — 15
- Be familiar with an example "drill-stem test" ............................................................................................. Slide — 16
- Be familiar with an example of a "semilog" drawdown test plot ................................................................. Slide — 17
- Be familiar with an example of a "log-log" drawdown test plot ................................................................. Slide — 18
- Be familiar with an example of a "semilog" buildup test plot ................................................................. Slide — 19
- Be familiar with the flow regimes encountered in pressure transient analysis (WBS, IARF, fractured wells) Slide — 20
- Be familiar with the properties that can be obtained from a pressure transient test .................................... Slide — 21
- Be familiar with the common plots/flow regimes typical for a pressure transient test ............................... Slide — 22
- Be familiar with the "Questions to Consider" for Pressure Transient Analysis (Challenges for PTA) ........ Slide — 23

**Pressure-Distance Plots — Pressure Transient Analysis:**
- Pressure-Distance Plots — Pressure Transient Analysis ........................................................................... Slides — 25-36
- Be familiar with and be able to apply the "radius of investigation" relation for transient radial flow ........ Slide — 26
- Be familiar with and be able to apply the "pressure distribution" solutions for radial flow .................... Slides — 26-27
- Be familiar with and be able to apply the "pseudo-steady-state flow" concept ........................................... Slides — 28-30
- Be familiar with the schematic of reservoir pressure for various flow conditions (radial flow) ............... Slides — 31-35
  - Constant rate, transient radial flow behavior [log(r) format] ............................................................... Slide — 31
  - Log-linear rate decline, transient radial flow behavior [log(r) format] .................................................. Slide — 32
  - Constant wellbore pressure, transient radial flow behavior [log(r) format] ....................................... Slide — 33
  - Constant rate, transient radial flow behavior [Cartesian r format] ....................................................... Slide — 34
  - Constant wellbore pressure, transient radial flow behavior [Cartesian r format] .................................. Slide — 35
- Be familiar with the "Questions to Consider" for Reservoir Pressure Trends ............................................ Slide — 36
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Pressure Transient Analysis: (Continued)

Basic Analysis Plots — Pressure Transient Analysis:
- Be familiar with and be able to apply models for "fractured wells" ....................................................... Slides — 53-58
- Be familiar with and be able to apply models for "unfractured wells" (radial flow) (+the skin factor) .. Slides — 50-52

PTA Model-based Analysis — Pressure Transient Analysis:
- Be familiar with the "Questions to Consider" for Conventional PTA Plots ........................................ Slide — 47

PTA Type Curves — Pressure Transient Analysis:
- Be familiar with the "Questions to Consider" for Reservoir Models .......................................................... Slide — 63
- Be familiar with the "Questions to Consider" for PTA Type Curves .......................................................... Slide — 76

PTA Field Examples — Pressure Transient Analysis:
- Unfractured oil well (SPE 11463) — Infinite-Acting Radial Flow (IARF) ................................................. Slide — 78
- Unfractured oil well (SPE 12777) — Infinite-Acting Radial Flow (IARF) .................................................. Slide — 79
- Unfractured oil well (SPE 13054) — Dual Porosity, Infinite-Acting Radial Flow (IARF) .......................... Slide — 80
- Unfractured oil well (SPE 18160) — Dual Porosity, Infinite-Acting Radial Flow (IARF) .......................... Slide — 81
- Fractured gas well (SPE 9975 — Well 5) — Hydraulically fractured gas well ........................................ Slide — 82
- Fractured gas well (SPE 9975 — Well 10) — Hydraulically fractured gas well ........................................ Slide — 83
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- Fractured oil well (SPE 103204 — Well 207) — Pressure fall-off test ......................................................... Slide — 85
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Production Analysis:

**Orientation — Production Analysis:**
- Be familiar with Semilog, and Log-Log plotting coordinates. Slides — 1-16
- Be familiar with the Objectives of Production Data Analysis. Slide — 2-3
- Be familiar with the data requirements (and issues) for production data analysis. Slide — 4
- Be familiar with the give production data example (SPE 15482). Slide — 5
- Be familiar with the required static data input for production analysis. Slide — 6
- Be familiar with the common issues with production data. Slide — 7
- Be familiar with the influence/impact of "allocated data" on production analysis. Slides — 8-9
- Be familiar with the influence/impact of a completion on the analysis of production data. Slides — 10-12
- Be familiar with the influence/impact of using surface rather than bottomhole pressure data. Slides — 13-15

**Integration of Results — Production Analysis:**
- Be familiar with the "Reservoir Integration" flowchart presented by Weber. Slide — 49
- Be familiar with the PTA topics which are relevant to well performance analysis. Slide — 40
- Be familiar with sandstone depositional systems. Slides — 31-32
- Be familiar with carbonate depositional systems. Slide — 33
- Be familiar with the Weber Example core: Permeability Characterization/Correlation. Slide — 34
- Be familiar with the Field Case: Womack Hill — Comparison of $k_{WPA}$ and $k_{WPS}$. Slide — 35
- Be familiar with the Field Case: Tordillo Field — Comparison of $h$ and $OOIP_{WPA}$. Slide — 36
- Be familiar with the Field Case: Tordillo Field — Comparison of $k$ and $k_{WPS}$. Slide — 37
- Be familiar with the Field Case: Santa Barbara — $k_{WPA}$, $k_{PTA}$ with $k_{log-mean}$. Slide — 38

**Integration of Geology — Production Analysis:**
- Be familiar with the influence/impact of "allocated data" on production analysis. Slide — 8-9
- Be familiar with the influence/impact of a completion on the analysis of production data. Slide — 10-12
- Be familiar with the influence/impact of using surface rather than bottomhole pressure data. Slide — 13-15

**Pressure Transient Analysis — Overlap with Production Analysis — Production Analysis**
- Be familiar with the current library of PTA models. Slide — 41
- Be familiar with the philosophy and objectives of PTA. Slides — 42-46
- Be familiar with the "Arun Field" example comparison of $(kh)_{PTA}$ versus $(kh)_{PA}$. Slide — 47
- Be familiar with the topics/issues related to Reservoir Simulation which are relevant to PA and PTA. Slide — 48
- Be familiar with the "Reservoir Integration" flowchart presented by Weber. Slide — 49
- Be familiar with the schematics "Reservoir Scales" (by Weber) and "Scaling-Up Process" (by Lasseter). Slide — 50

**History of Production Analysis — Production Analysis:**
- Be familiar with the historical milestones for Production Analysis. Slide — 52
- Be familiar with the historical milestones for Production Analysis. Slide — 53
- Be familiar with historical Production Analysis methods — 1920's. Slides — 54-58
  - Early Data Analysis Plots — Reserves (EUR) versus Average Flowrate (Cartesian). Slide — 56
  - Rate-Time Plots: Cartesian, Semilog (rate), and Log-log plots. Slides — 57-58
- Be familiar with historical Production Analysis methods — 1940's. Slides — 59-63
  - Arps' (Empirical) Rate Relations — Exponential, Hyperbolic, and Harmonic Rate Relations. Slides — 60-61
  - Be familiar with and be able to derive the Arps' Exponential Rate Relation. Slide — 62
  - Arps' Example. Slide — 63
- Be familiar with historical Production Analysis methods — 1960's. Slides — 64-72
  - Fetkovich: Empirical methods ("depletion" stem (Arps' empirical rate-time relations)). Slides — 65-66
  - Fetkovich: Analytical methods ("transient" (analytical) "stems). Slide — 67
  - Fetkovich: Composite Type Curve ("transient" (analytical) + "depletion" (Arps' empirical) "stems). Slides — 68-70
  - Fetkovich-Carter: Type Curve for gas flow applications ($p_d = constant$). Slide — 71
Production Analysis: (continued)

History of Production Analysis — Production Analysis
- Be familiar with historical Production Analysis methods — 1980's .......................................................... Slides — 72-84
- Superposition — Van Everdingen and Meyer Method (rigorous superposition) .................................................. Slides — 73-74
- Window Analysis — Athianchagorn, Horne, and Kikani Method ........................................................................... Slide — 75
- Pseudosteady-State Flow Relations — Rate Normalization and Material Balance Time ........................................... Slides — 76-82
- Palacio/Blasingame Type Curve — Fetkovich TC, Auxiliary Functions and Material Balance Time .................. Slides — 83-84
- Be familiar with historical Production Analysis methods — 2000's .......................................................... Slides — 85-92
- Orientation to Modern Production Analysis ........................................................................................................ Slide — 86
- Loebel Well Example (from SPE 15482) ............................................................................................................... Slides — 87-91
- Perspectives on the Future of Production Analysis ................................................................................................ Slide — 92

Basic Methods for Production Analysis — Production Analysis
- Basic Methods for Production Analysis — Production Analysis .................................................................................. Slides — 93-114
- Be familiar with the Basic Analysis Tools for Production Analysis (PA) [Orientation Page] ........................................ Slide — 94
- Arps Plot: Semi-Analytical Rate-Time Analysis: .................................................................................................... Slides — 95-98
  - Be familiar with and be able to use a plot of log(rate) versus time to estimate EUR ............................................. Slides — 96-98
  - Be familiar with and be able to apply the Arps' rate-time relations .......................................................................... Slide — 96
- EUR Plot: Semi-Analytical Rate-Cumulative Analysis: ............................................................................................. Slides — 99-103
  - Be familiar with and be able to use a plot of rate versus cumulative production to estimate EUR ....................... Slides — 101-103
  - Be familiar with and be able to apply the Arps' rate-cumulative relations ............................................................. Slide — 100
- Fetkovich (Log-Log) Plot: Type Curve Analysis: (constant pwf) ................................................................................. Slides — 104-107
  - Be familiar with and be able to use a plot of log(rate) versus log(time) (i.e., "Fetkovich" type curve) ................................ Slide — 107
- Bubba Approach: Analytical Gas Solution: (constant pwf) ....................................................................................... Slides — 108-114
  - Be familiar with and be able to use the "Bubba" plot (Gp versus square of Gp) ............................................................... Slides — 108-114
  - Be familiar with and be able to use the "Bubba" rate-cumulative relation to estimate EUR ........................................ Slides — 111-112

Advanced Analysis Methods for Production Analysis — Production Analysis
- Advanced Analysis Methods for Production Analysis — Production Analysis .......................................................... Slides — 115-128
- Be familiar with the Advanced Analysis Concepts for Production Analysis (PA) [Orientation Page] ................ Slide — 115
- Exact Superposition Formulation: (Reservoir Model)
  - Be familiar with and be able to apply the (exact) "superposition" relations for flowrate and pressure ...................... Slide — 118
- Superposition Formulation for Pseudosteady-State:
  - Be familiar with and be able to apply the "Black Oil" PSS Equations .................................................................... Slide — 120
  - Be familiar with and be able to apply the "Dry Gas" PSS Equations ................................................................. Slide — 121
- Auxiliary Functions:
  - Be familiar and be able to apply the "auxiliary" plotting functions for PA type curve sequence ..................... Slides — 122-123
- Assumptions, Limitations, and Practical Considerations:
  - Be familiar with the data requirements for performing a modern PA sequence ................................................. Slide — 125
  - Be familiar with the limitations for performing a modern PA sequence ............................................................. Slides — 124-127
  - Be familiar and be able to apply the "multifield" Material Balance Time ............................................................. Slide — 128
- Appendix — Library of Decline Type Curves
  - Be familiar with and be able to use the "Decline Type Curves" included in this library .................................... Slides — 129-141

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- Conclusions Guidelines/Pitfalls/Recommendations — Production Analysis .......................................................... Slides — 142-149
- Be familiar with the available PA tools and the issues at present ........................................................................... Slide — 143
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- Be familiar with the "pitfalls" for PA (pressure and flowrate issues) ............................................................................ Slide — 145
- Be familiar with the recommendations/caveats for PA (pressure/flowrate issues, data mgmt., etc.) .................. Slides — 146-147
- Be familiar with the "reality checks" for PTA/PA (volume averaging, model limitations, etc.) .......................... Slide — 148
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Semi-Analytical Rate Relations for Oil and Gas Flow:
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  - Arps relations (exponential, hyperbolic, and harmonic) ................................................................................... Slides — 4-9
  - Derivation of Arps' exponential decline relation .............................................................................................. Slide — 10
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  - Fetkovich Gas Flow Relation ............................................................................................................................. Slides — 14-15
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- SPE 116731 (Exponential vs. Hyperbolic Decline in Tight Gas Sands) .................. Slides — 2-10
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  - Introduction to "power-law exponential" rate decline model ................................ Slide — 5
  - Illustration of diagnostics/behavior for the "power-law exponential" rate decline model .......... Slides — 6-10
- SPE 123298 (A Simple Methodology for Direct Estimation of Gas-in-place and Reserves) ... Slides — 11-15
  - Presentation of the simplified gas rate analysis relation ...................................... Slides — 12-13
  - Illustration/demonstration of the simplified gas rate analysis relation ....................... Slides — 14-15
- SPE 125031 (Decline Curve Analysis for HP/HT Gas Wells: Theory and Applications) ....... Slides — 16-23
  - Presentation of analytical gas flow relations — functions and diagnostic plots .......... Slides — 17-19
  - Demonstration of these analytical gas flow relations .......................................... Slides — 20-24
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  - Presentation of a new series of gas flow models for unconventional reservoirs .......... Slides — 25-27
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  - Demonstration plots for these new rate-decline models ..................................... Slides — 29-34