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

### Introduction to Reservoir Engineering:
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- 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 Map — Archie (1950) ......................................................... Slide — 11
- Be familiar with Petrophysics — Early Correlation Concepts ................................................. Slide — 12
- Be familiar with Phase Behavior .......................................................................................... Slide — 13-14
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  - History of Reservoir Engineering — Orientation ............................................................... Slide — 28
  - History of Reservoir Engineering — Timelines ................................................................. Slide — 29
  - History — Tasks of the Reservoir Engineer ....................................................................... Slide — 30
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  - Geology — Carbonate Depositional Systems — $\phi$ and $k$ ............................................. Slide — 5
- Be familiar with Petrophysics .......................................................................................... Slides — 6-7
  - Petrophysics — Effect of Small-Scale Heterogeneities ....................................................... Slide — 6
  - Petrophysics — Example — $k_{WTB}, k_{PTA}$ with $k_{bulk}$ .................................................... Slide — 7
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  - Flow Concepts — High-Velocity Flow in Porous Media .................................................... Slide — 13
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- Be familiar with Reservoir Petrophysics .......................................................................... Slides — 15-26
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  - Material Balance — Volumetric Gas Reservoir Case .......................................................................... Slide — 9
  - Material Balance — Abnormally-Pressured Gas Reservoir Case ........................................................ Slide — 10
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Pressure Transient Analysis:

Orientation — Pressure Transient Analysis:
- Be familiar with the objectives of Pressure Transient Analysis ............................................................. Slide — 2
- 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 .................................................... Slide — 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 concepts/relations for early 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
- Be familiar with the "Questions to Consider" for Pressure Transient Analysis (Orientation for PTA) ........ Slide — 12

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 — 27-28
- Be familiar with and be able to apply use the "pseudosteady-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 identify and use the appropriate relations for "wellbore storage". Slides — 38-43
  - Be familiar with the base relations for wellbore storage. Slide — 38
  - Be familiar with the schematic Cartesian plots for wellbore storage distorted PTA data. Slide — 39
  - Be familiar with the "exponential approximation" solution for wellbore storage. Slide — 40
  - Be familiar with and be able to apply the "Bourdet-Gringarten" wellbore storage "type curve". Slide — 41
  - Be familiar with and be able to apply the Cartesian plot for wellbore storage distorted PTA data. Slide — 42
  - Be familiar with and be able to apply the Log-log plot for wellbore storage distorted PTA data. Slide — 43
- Be familiar with the "Questions to Consider" for Conventional PTA Plots. Slides — 44-45
  - Be familiar with and be able to apply the Semilog plot for PTA data during the IARF regime. Slide — 44
  - Be familiar with and be able to apply the Log-log plot for PTA data during the IARF regime. Slide — 45
- Be familiar with and be able to identify and use the Muskat-Arps late-time Pressure Buildup (PBU) plot. Slide — 46
- Be familiar with the "Questions to Consider" for Conventional PTA Plots. Slide — 47

PTA Model-based Analysis — Pressure Transient Analysis:
- Be familiar with the Orientation Slide for PTA Model-Based Analysis. Slide — 49-62
  - Be familiar with and be able to apply models for "fractured wells". Slides — 50-52
  - Be familiar with and be able to apply models for "fractured wells". Slides — 53-58
- Be familiar with the "Questions to Consider" for Reservoir Models. Slide — 63

PTA Type Curves — Pressure Transient Analysis:
- Be familiar with the "Questions to Consider" for PTA Type Curves. Slide — 64-76
  - "Bourdet-Gringarten" Type Curve: WBS and IARF. Slide — 65
  - "Ansah" Type Curve: Late-Time Pressure Buildup. Slide — 66
  - "Stewart" Type Curves: Sealing Faults. Slide — 67
  - "Cinco" Type Curves: Vertically Fractured Well (No WBS). Slide — 68-69
  - "Economides" Type Curves: Vertically Fractured Well (with WBS). Slide — 70-72
  - "Onur" Type Curves: Naturally Fractured Reservoirs (No WBS). Slide — 73-74
  - "Angel" Type Curves: Naturally Fractured Reservoirs (with WBS). Slide — 75
- 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
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  - 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
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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:
- Orientation — Production Analysis ................................................................. Slides — 1-16
- Be familiar with Semilog, and Log-Log plotting coordinates .......................... Slides — 2-3
- Be familiar with the Objectives of Production Data Analysis ............................. Slide — 4
- 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:
- Integration of Results — Production Analysis .................................................. Slides — 16-xx
- Be familiar with and be able to apply the "Integration of Results" methods ........ Slide — 17
- Be familiar with and be able to apply the "Correlation of PA Results" methods ....... Slides — 16-23
- Be familiar with the most fundamental concepts of "Well Deliverability" .............. Slide — 24
- Be familiar with the well/facilities flow system and the critical points in the system Slide — 25
- Be familiar with the concept of reservoir heterogeneity and how this affects PA and PTA Slide — 26
- Be familiar with the "scales of results" issues that occur when trying to relate PA and PTA results Slide — 27
- Be familiar with and be able to apply the "Guidelines for Performance-Based Reservoir Characterizations" Slide — 28
- Be familiar with the use of reservoir simulation to "integrate" the well model(s) and performance data Slide — 29

Integration of Geology — Production Analysis:
- Integration of Geology and the Analysis of Reservoir Performance — Production Analysis Slides — 30-38
- 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 \( k_{SWPA} \) 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 \( h \) and \( kWPA \) Slide — 37
- Be familiar with the Field Case: Santa Barbara — \( k_{WPA} \), \( k_{PTA} \) with \( k_{log\ mean} \) Slide — 38

Pressure Transient Analysis — Overlap with Production Analysis — Production Analysis:
- Pressure Transient Analysis — Overlap with Production Analysis — Production Analysis Slides — 39-50
- Be familiar with the PTA topics which are relevant to well performance analysis Slide — 40
- 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 \((kh)_{PTA} \) 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:
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- Be familiar with the orientation points provided for Production Analysis .......... Slides — 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 Slides — 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
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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
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  - Be familiar with historical Production Analysis methods — 2000's .......................................................... Slides — 85-92
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- 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 — 96-99
  — 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
  - Buba Approach: Analytical Gas Solution: (constant pwf) ................................................................. Slides — 108-114
    — Be familiar with and be able to use the "Buba" plot (qg versus square of Gp) ........................................ Slides — 108-114
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  - Be familiar with the Advanced Analysis Concepts for Production Analysis (PA) [Orientation Page] .......... Slide — 116
  - 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
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  - 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 "multiwell" 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

Conclusions Guidelines/Pitfalls/Recommendations — Production Analysis

- Conclusions Guidelines/Pitfalls/Recommendations — Production Analysis .............................................. Slides — 142-149
  - Be familiar with the available PA tools and the issues at present ............................................................. Slide — 143
  - Be familiar with the practical guidelines for PA ....................................................................................... Slide — 144
  - 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
  - Be familiar with references for Production Analysis ................................................................................. Slide — 149

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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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- Specialized Gas Flow Relations .............................................................................................................. Slides — 12-19
  — 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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