Advanced PVT & EOS Fluid Characterization
State of The Art Petroleum Fluid Phase Behavior Modelling

Date: 5th – 9th November 2012
Location: Kuala Lumpur, Malaysia

Distinguished Masterclass Instructor

Aaron A. Zick, Ph.D.
Founder and President
Zick Technologies, Inc.

Over 28 years experience in equation-of-state modeling of petroleum fluid thermodynamics

Summary of Accomplishments
- Discovered the Condensing/Vaporizing Gas Drive mechanism for miscible displacement
- Created the EOS reservoir fluid characterization for the Prudhoe Bay Miscible Gas Project
- Wrote PhazeComp, a state-of-the-art program for EOS phase behavior modeling, fluid characterization, and the calculation of minimum miscibility conditions
- Consulted for major oil companies, world-wide, on phase behavior experimentation and equation-of-state modeling
- Taught numerous industry courses on advanced PVT, EOS fluid characterization, and multi-contact miscibility
- Member of the Society of Petroleum Engineers (SPE)

Masterclass Objectives
- UNDERSTAND Basic Petroleum Fluid Thermodynamics (Phase Behavior and the Relationships between Pressure, Volume, Temperature and Composition)
- DISCOVER Black-Oil and Equation-of-State Phase Behavior Modeling
- APPLY Accurate and Proper PVT Experiments for Petroleum Fluids
- GAIN in depth knowledge on EOS Fluid Characterization Techniques - Developing and Tuning
- PRACTICE accurate estimation of In Situ Reservoir Fluid Compositions
- OBTAIN Black-Oil Properties from a Tuned EOS
- UNDERSTAND Minimum Miscibility Pressures and Enrichments for Multi-Contact Miscible Displacements

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Masterclass Overview

The knowledge of petroleum fluid phase behavior plays a crucial role throughout the Oil & Gas industry, from reserves estimation to reservoir production to surface processing to transportation and storage. Phase behavior modeling is vital, but often taken for granted. Whether an equation of state or a simple black-oil model is used, it needs to be specifically built and tuned to the experimental PVT data for each unique fluid. Only then can the model be used to make the necessary engineering predictions.

The masterclass is prepared mainly with the job requirements of reservoir engineering and process engineering in mind, although pipeline, transportation, and refining engineers would also benefit. Prior phase behavior experience would be helpful, but not required. A full range of relevant topics will be covered, including basic thermodynamics, black-oil and EOS modeling, PVT experiments, estimation of in situ reservoir compositions, black-oil properties from an EOS, and multi-contact miscibility.

Classroom exercises with actual PVT data will provide hands-on experience with PhazeComp, state-of-the-art EOS characterization and phase behavior modeling software from Zick Technologies, Inc. Participants will leave with enhanced abilities to analyze and utilize PVT data, and to build and use EOS and black-oil petroleum fluid phase behavior models.

Specially Designed for

Intended for the reservoir, production, or processing engineers or managers who would like to learn more about:

- Basic Petroleum Fluid Thermodynamics (Phase Behavior and the Relationships between Pressure, Volume, Temperature and Composition)
- Black-Oil and Equation-of-State Phase Behavior Modeling
- PVT Experiments for Petroleum Fluids
- EOS Fluid Characterization Techniques — Developing and Tuning
- Estimation of In Situ Reservoir Fluid Compositions
- Obtaining Black-Oil Properties from a Tuned EOS
- Minimum Miscibility Pressures and Enrichments for Multi-Contact Miscible Displacements

From Oil & Gas industry, particularly the sub-sectors below:

- Upstream Oil & Gas Production
- Gas Processing & Oil Refining
- Downstream Petrochemical / Chemical
- Oil & Gas Transportation & Storage

Masterclass Agenda

DAY 1

1) Basic Thermodynamics
   a) Gibb’s phase rule
   b) Single component
      i) Ideal gas law
      ii) Generalized compressibility factor
      iii) Phase transitions and phase equilibrium
      iv) Pressure-Volume-Temperature (PVT) relationships
         (1) P-T (vapor pressure) diagrams
         (2) P-V diagrams
      v) Equation-of-state (EOS) representations
         (1) Van der Waals EOS
         (2) Generalized 5-parameter cubic EOS
         (3) Soave-Redlich-Kwong EOS
         (4) Peng-Robinson EOS
         (5) Peneloux volume shift parameter
         (6) EOS advantages and limitations
   c) Two components
      i) PVT/compositional relationships
         (1) P-T diagrams (phase envelopes)
         (2) P-x diagrams (phase envelopes)
         (3) P-V diagrams
         (4) K-values
      ii) EOS representations
         (1) Binary interaction parameters
         (2) Advantages and limitations
      iii) Black-oil representations
         (1) Two components: surface oil and surface gas
         (2) Two phases: reservoir oil and reservoir gas
         (3) Phase equilibrium and phase property dependencies
            (a) Composition (amounts of surface oil and surface gas)
            (b) Pressure (through formation volume factors, gas/oil and oil/gas ratios)
   d) Three or more components
      i) PVT/compositional relationships
         (1) P-T diagrams (phase envelopes)
         (2) P-x diagrams (phase envelopes, swelling diagrams)
         (3) Ternary diagrams
         (4) Quaternary diagrams
2) Equation-of-state Phase Behavior Modeling
   a) Software
   b) Input requirements
      i) EOS
      ii) List of components
      iii) Characterization parameters
      iv) Composition, temperature, pressure
      v) Specifications for experiments to simulate
   c) Additional useful input
      i) Correlation parameters
      ii) Gamma distribution parameters
      iii) Component boiling points and specific gravities
      iv) Experimental data (for tuning the characterization)
   d) Component property estimations
   e) Gamma distribution fitting
   f) Plus fraction characterization
      i) Gamma splitting
   ii) Pseudocomponent property estimations
   g) Pseudoization
      i) Component lumping
      ii) Pseudocomponent property estimations

3) PVT Experiments for Petroleum Fluids
   a) Traditional black oil experiments
      i) Saturation pressure determinations
      ii) Density (API gravity) measurements
      iii) Separator tests
      iv) Constant composition expansions
      v) Differential liberations
      vi) Constant volume depletions
   b) Building black oil tables directly from PVT data
   c) Compositional experiments
      i) Molecular weight measurements
      ii) Compositional analyses
         (1) True boiling point distillation
         (2) Simulated distillation by gas chromatography
         (3) Crude assays
      iii) Equilibrium phase compositions
      iv) Swelling experiments
      v) Multi-contact vaporization experiments
      vi) Slim tube displacements

4) EOS Characterization Tuning
   a) Picking the right software
   b) Inputting measured compositions
   c) Tuning correlations to honor molecular weights and densities
   d) Deciding on component strategy (to pseudoize early or late)
   e) Fitting a gamma distribution
   f) Initializing the characterization
      i) Specifying the component suite
      ii) Estimating initial characterization parameters
         (1) Library properties
         (2) Gamma distribution properties
         (3) Correlated properties
   g) Inputting measured data
      i) All sample compositions, adjusted for potential lab errors
         (1) Molecular weight measurement errors
         (2) Gas chromatography errors
         (3) Inconsistencies with separator gas/oil ratios
      ii) All PVT and compositional data from all PVT experiments

h) Guidelines for choosing regression variables
   i) Leave previously tuned correlations alone
   ii) Choose parameters with the least certainty and the most influence
      (1) Binary interaction parameters
      (2) Critical properties and/or boiling point of the heaviest pseudocomponent
      (3) Critical properties and/or boiling points of other pseudocomponents
   iii) Keep parameters physically realistic and monotonic with carbon number
      (1) Bound all adjustments realistically
      (2) Adjust as few properties as absolutely necessary
      (3) Adjust properties for groups of components uniformly
      (4) Adjust critical properties rather than EOS A and B parameters
      (5) Adjust specific gravities rather than volume shifts
      (6) Adjust boiling points rather than acentric factors
   iv) Regress on viscosity parameters separately
      (1) Fit phase behavior data first, with no weighting on viscosity data
      (2) Fit weighted viscosity data with all non-viscosity parameters frozen
         i) Trial and error
            i) Try modifying the data weighting
            ii) Try modifying the choice of regression variables
               iii) Learn to recognize data outliers and discrepancies
               iv) Learn to recognize good matches from poor matches

5) Estimating Reservoir Fluid Compositions
   a) The “Equilibrium Contact Mixing” method
   b) Mathematical decontamination
   c) Gravity induced thermodynamic segregation

6) Black Oil Properties from a Tuned EOS
   a) Advantages
      i) More accurate than experimentally derived black oil tables
      ii) Flexibility in choice of samples, depletion processes, and surface processes
      iii) Consistency between black oil and compositional simulation
   b) Procedure
      i) Specify the oil and/or gas samples
      ii) Specify the all-important surface process
      iii) Simulate appropriate depletion experiment(s)
      iv) Pass equilibrium phases from each stage through surface process
      v) Determine surface amounts and properties for each depleted fluid
      vi) Manipulate results into reservoir simulator format

7) Minimum Miscibility Pressures and Enrichments
   a) Mechanisms
      i) Condensing gas drive
      ii) Vaporizing gas drive
      iii) Condensing/vaporizing gas drive
   b) Experimental determination
   c) EOS predictions
      i) Slim tube simulations
      ii) Multi-cell, multi-contact mixing simulations
      iii) Predictions by the method of characteristics
Aaron A. Zick, Ph.D.
Founder and President
Zick Technologies, Inc.

President, Zick Technologies (Since 10/93).

Petroleum engineering consulting and software development, specializing in the area of reservoir fluid phase behavior modeling. References available on request. Key achievements:

• Developed numerous equation-of-state and black-oil fluid characterizations for various major oil companies and as a sub-contractor for Pera A/S.

• Recommended phase behavior experimentation and modeling guidelines for several major oil companies.

• Wrote PhazeComp, a new, state-of-the-art program from Zick Technologies for equation-of-state phase behavior modeling, reservoir fluid characterization, and the robust, efficient calculation of minimum miscibility conditions.

• Wrote Streamz, unique Petrostreamz A/S software for translating, manipulating, and managing vast quantities of fluid stream information.

• Designed and helped write Pipe-It, unique Petrostreamz A/S software for managing and manipulating petroleum resources, processes, and projects.

• Taught numerous industry courses on phase behavior, equations of state, reservoir fluid characterization, and miscible gas injection processes.

• Designed and helped implement a new set of equation-of-state routines for the in-house reservoir simulator of a major oil company.

• Advised the architects of a major commercial reservoir simulator on ways to significantly improve their equation-of-state routines.

Director of Research, Reservoir Simulation Research Corporation (6/91–10/93).

Responsible for the research and development of more efficient, accurate, and reliable techniques for modeling reservoir fluid phase behavior within MORE® (a fully-compositional, equation-of-state reservoir simulator). Also responsible for improving three-dimensional visualization of reservoir simulator output, and for occasional consulting work. Key achievements:

• Designed and implemented new equation-of-state solution algorithms for MORE®, improving both efficiency and robustness while using less memory.

• Developed a powerful and flexible interface between MORE® and TECPLLOT™ (three-dimensional surface contouring software from AMTEC Engineering).

Senior Principal Research Engineer, ARCO Oil and Gas Company (9/83–5/91).

Developed expertise in reservoir fluid phase behavior, phase behavior modeling, compositional reservoir simulation, and relative permeability modeling. Designed and analyzed PVT experiments. Created equation-of-state reservoir fluid characterizations. Developed ARCO’s phase behavior modeling software and relative permeability modeling software. Helped develop several of ARCO’s compositional and limited compositional reservoir simulators. Key achievements:

• Discovered the true, condensing/vaporizing mechanism of oil displacement by enriched hydrocarbon gases.

• Represented ARCO on the Prudhoe Bay co-owners’ Enhanced Oil Recovery Task Force for the Prudhoe Bay Miscible Gas Project.

• Designed and analyzed most of the PVT and slim-tube experiments for the Prudhoe Bay Miscible Gas Project.

• Created the equation-of-state reservoir fluid characterization adopted by the operating companies for the Prudhoe Bay Miscible Gas Project.

• Developed the miscibility pressure correlations used by the facility operators for the Prudhoe Bay Miscible Gas Project.

• Developed EOSPHASE, a then state-of-the-art program for equation-of-state phase behavior modeling, reservoir fluid characterization, and the robust, efficient calculation of minimum miscibility conditions.

• Developed SLIMTUBE, a special-purpose, equation-of-state simulator for slim-tube displacements.

• Developed new, compositionally-consistent, three-phase relative permeability models for ARCO’s compositional simulators and wrote data-fitting software for those models.

• Developed the phase behavior and relative permeability routines for a new, limited compositional reservoir simulator and assisted on other aspects of it.

• Continually added improvements to various in-house reservoir simulators.

• Regularly taught in-house courses on the phase behavior of miscible gas displacement processes.

Client List
- ARCO Oil & Gas Company
- Abu Dhabi National Oil Company
- Norsk-Hydro ASA
- Norwegian University of Science and Technology (NTNU)
- Maersk Oil and Gas AS
- Kuwait Oil Company
- ENI UK Ltd.
- Shell International Exploration and Production B.V.
- CEPSA E&P
- Wintershall AG
- Abu Dhabi Marine Operating Company
- Abu Dhabi Company for Onshore Oil Operations
- Petroleum Development Oman
- Marathon Oil U.K., Ltd.
- Statoil
- Erdgas Erdöl GmbH
- PERA AS

AWARDS
1990: ARCO President’s Award for “Advancing and Applying Compositional Technology.”

1990: ARCO Vice President’s Award for “Limited-Compositional Reservoir Simulator Development.”

1986: ARCO Special Achievement Award for “Development of the State-of-the-Art EOSPHASE Phase Behavior Program.”

1978: National Science Foundation Graduate Fellowship.
**Course Details**

**Title**: Advanced PVT & EOS Fluid Characterization  
**Date**: 5th - 9th November 2011  
**Location**: Kuala Lumpur, Malaysia

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