

Hydrocarbon Reservoirs and Production: Thermodynamics and Rheology

A comprehensive course by
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Palo Alto, California USA
August 3 – 7, 2015

Scope

This five-day intensive course offers a unified thermodynamic framework (bulk equilibrium, bulk non-equilibrium, interfacial, and thin films) and rheological aspects of a large number of topics in relation to hydrocarbon energy production and environmental stewardship. Important subjects from molecular structure in bulk and in at the interface, low salinity water injection, shale gas, shale light oil, heavy and super-heavy oil production, asphaltene deposition and removal, hydrate flow assurance, wax mitigation, CO₂ injection in light and heavy oil reservoirs, efficient and robust phase-split computations, emulsions, microemulsions, and past climate changes are covered to the level that computations can be performed. A focus of the course will be on thermodynamics of nano-particles and the vast opportunity that they offer for process improvement, efficiency, and safety. Efficient molecular dissolution of asphaltenes, and colloidal stabilization will be discussed in detail. The structures in various salt solutions in relation to micellization and microemulsion, and low salinity water injection will be covered. The concepts will be presented through cartoons to facilitate understanding of a broad range of topics.

Items of discussion in the course include:

- Unique properties of CO₂ in comparison to nitrogen and methane and other fluids in relation to improved oil recovery in fractured and unfractured light, heavy, and super-heavy oil reservoirs. Field experiences from different parts of the world will be discussed.
- Mechanisms of low salinity water injection
- Effect of salinity and different types of salts on wettability, dissolution, and in micellization and microemulsion
- Shale gas and shale light oil reservoirs and unique features of shale rocks
- Phase behavior of bitumen and various gases and normal alkanes and why normal alkane injection in heavy oils may encounter challenges.
- Strength of cubic-plus-association EOS for a variety of complex problems in aqueous mixtures and asphaltene precipitation
- Predictive capability of EOS and reservoir fluid characterization
- CO₂ mixing with reservoir fluids; Modeling of diffusion flux in reservoir simulators based on chemical potential driving forces
- Asphaltene and resin molecular structure and interaction with water and viscosity reduction
- Formation of nano-particles of asphaltenes and hydrates, and advantage of surface property changes to bulk phase property changes
- Effect of size of nano-particles on melting, and on saturation pressure
- Efficient two- and three-phase split computations
- The link between irreversible thermodynamics and complex diffusion processes and past climate change modeling
- Asphaltene removal from pipes and from rocks by efficient molecular dissolution
- Species distribution in hydrocarbon reservoirs from irreversible thermodynamics
- Hydrate particle stabilization and advancing hydrate flow assurance by small amounts of functionalized molecules
- Basic-level understanding of microemulsion and micellization and application to a variety of problems in hydrocarbon energy production.
- Interfacial Rheology
- Interfacial rheology measurement interpretation in relation to improved oil recovery

Schedule

The course will begin at 8:30 a.m. on August 3, and will end at noon on August 7. Daily sessions will be from 8:30 a.m. to 4:30 p.m. with a lunch break from 12:15 p.m. to 1:30 p.m. Part of the afternoon sessions will be devoted to discussion.

General course agenda

Day 1

8:30 a.m. – 9:30 a.m.

- Overview of molecular structures in petroleum systems and various issues in oil and gas production from thermodynamic and rheology concepts and modern techniques
- Use of thermodynamic principles in the study of shale gas, shale light oil, flow assurance, and improved oil recovery
- Use of functionalized molecules to drastic change of properties
- Property change with size in the nm range

9:30 a.m. – 10:30 a.m.

- Brief review of bulk phase equilibrium thermodynamics
- Removal of fluids from a container and observation of pressure increase!

10:30 a.m. – 10:45 a.m.

- Coffee break

10:45 a.m. – 12:15 p.m.

- General theory of bulk-phase equilibrium thermodynamics in relation to gravity effect and interface effects, and electric field
- How can we increase or decrease normal boiling by the container and phase size?

12:15 p.m. – 1:30 p.m.

- Lunch break

1:30 p.m. – 2:30 p.m.

- Phase behavior and volumetric description of fluids and fluid mixtures and petroleum fluids from cubic equations of state (EOS)
- Nature of delay and kinetics in various processes including vaporization, condensation, crystallization, and melting
- Why crystallization is so much different from melting
- Why the PR-EOS works so well for reservoir fluids

2:30 p.m. – 3:15 p.m.

- Concept of molecular association
- Phase behavior of water and water-CO₂ mixtures by the cubic-plus-association (CPA) EOS
- Phase behavior in asphaltene precipitation by CPA-EOS

3:15 p.m. – 3:30 p.m.

- Coffee break

3:30 p.m. – 4:30 p.m.

- Phase behavior of bitumen with CO₂ and normal alkanes by CPA-EOS and PR-EOS
- Discussions and presentation of examples

Day 2

8:30 a.m. – 9:00 a.m.

- Characterization of reservoir fluids for modeling of various processes, including equilibria of vapor-liquid, vapor-liquid-liquid, wax precipitation, and asphaltene precipitation

9:00 a.m. – 10:30 a.m.

- Stability and criticality concepts and criteria, and applications in problems of hydrocarbon reservoirs and production
- Gibbs free energy surface analysis; How rugged is Gibbs free energy surface? Tangent plane distance analysis

10:30 a.m. – 10:45 a.m.

- Coffee break

10:45 a.m. – 12:15 p.m.

- Two- and three-phase split computations; Stability testing; How to perform phase-split computations with any number of phases with large number of components

12:15 p.m. – 1:30 p.m.

- Lunch break

1:30 p.m. – 2:30 p.m.

- General theory of irreversible thermodynamics; Fickian, thermal, and pressure diffusion flux expressions; How can oil float on top of lighter gas forever! Example is Yufutsu field in Japan. This is possible through thermal effects.

2:30 p.m. – 3:15 p.m.

- Species distribution in hydrocarbon reservoirs; Past climate changes
- Why mixing can separate the components in a hydrocarbon reservoir? The result is a high variation of horizontal composition change in a connected domain.

3:15 p.m. – 3:30 p.m.

- Coffee break

3:30 p.m. – 4:30 p.m.

- Introduction to shale-gas and shale-light oil reservoirs
- Condensation and vaporization in nano-pores greater than 8 nm
- Why condensation and vaporization can be drastically different in single components and in multicomponents! Sometimes the opposite of each other!
- Examples and discussion

Day 3

8:30 a.m. – 9:30 a.m.

- Brief introduction to density functional theory (DFT), molecular simulations and molecular dynamics simulations; Grand potential and not Gibbs free energy is the thermodynamic function of choice in some nano-scale problems. One key advantage is that there is no need for knowledge of pressure! Simple concepts and vast applications

9:30 a.m. – 10:30 a.m.

- Inhomogeneous fluid description in small confinement; Phase behavior in shale porous media and in pores less than 8 nm; Adsorption and other mechanisms are readily computed!
- Why use of EOS with adjusted T_C and P_C should be avoided in phase behavior in shale small pores.

10:30 a.m.–10:45 a.m.

- Coffee break

10:45 a.m. – 12:15 p.m.

- Flow in shale nano-pores
- Limitations of Knudsen and Klinkenberg flow expressions
- Flow in shale nano-pores from molecular dynamics simulations

12:15 p.m. – 1:30 p.m.

- Lunch break
- 1:30 p.m. – 3:15 p.m.
- Introduction to micellization and emulsion
 - Thermodynamics of micellization and microemulsion; Effect of different salts; Why different salt molecules are so different in their effectiveness?
 - Emulsion flow in porous media. Higher flow rates give lower pressure drops. This makes use of Darcy's law inappropriate! This also makes water-in-oil emulsion undesirable.
 - Asphaltene colloidal stabilization in petroleum fluids by functionalized micelles; Molecular dissolution of asphaltenes in petroleum fluids with very low concentration of acidic surfactants; Dissolution of deposited asphaltene molecules back into petroleum fluids
- 3:15 p.m. – 3:30 p.m.
- Coffee break
- 3:30 p.m. – 4:30 p.m.
- Effect of water and brine on asphaltene precipitation and deposition
 - Hydrate anti-agglomeration; Hydrate slurry and hydrate powder by functionalized molecules at low concentrations
 - Discussions

Day 4

- 8:30 a.m. – 10:30 a.m.
- Introduction to interfacial thermodynamics
 - New phase formation and driving force. Induction time.
 - Effect of charge on bubble nucleation and condensation
 - Solution-gas drive in permeable media
- 10:30 a.m.–10:45 a.m.
- Coffee break
- 10:45 a.m. – 12:00 p.m.
- Thermodynamics of thin films. Thin film description.
 - Effect of salt concentration on film thickness
- 12:00 p.m. – 1:00 p.m.
- Lunch break
- 1:00 p.m. – 2:00 p.m.
- The class will be introduced to the science of rheology, which concerns the flow and deformation of complex, non-Newtonian liquids. This subject, which links together fluid mechanics and material science, has great application in the recovery of oil from porous media, wax and hydrate flow assurance, drilling operations that employ complex muds, the design of fracturing fluids, and the stability of oil-water emulsions.
- 2:00 p.m. – 2:45 p.m.
- Introduction to rheology, the stress tensor in flowing liquids and the rate of strain tensor. Definition of rheological material functions (viscosity, normal stress differences, compliance, dynamic moduli). Shear rheometry and constitutive models.
- 2:45 p.m. – 3:15 p.m.
- The design of rotational shear rheometers
- 3:15 p.m. – 3:30 p.m.
- Coffee break
- 3:30 p.m. – 4:30 p.m.
- Application of rotational shear rheometry to fluids in the production of oil

Day 5

- 8:30 a.m. – 9:45 a.m.
- Extensional rheometry. The extensional viscosity of mobile liquids. The design of extensional rheometers and their application to liquids used in enhanced oil recovery.

9:45 a.m.–10:00 a.m.

- Coffee break

10:00 a.m. – 11:00 a.m.

- Interfacial rheology. Classification of complex fluid interfaces. Interfacial rheological material functions. Design of interfacial rheometers. Application to emulsion stability. The role of asphaltenes in emulsion stability.

11:00 a.m. – 11:30 a.m.

- Review and applications of rheological measurements in oil production.

11:30 a.m. – 12:00 p.m.

- Review of the course and discussion

Fees and Registration

The fee for attendance is US \$2,600. The rate for RERI's member companies is US \$2,200 per person. The course fee includes a copy of the 2015 book, *Thermodynamics and Applications in Hydrocarbon Energy and Production*, and a file containing relevant write-ups and papers. A limited number of academic discounts for PhD students and faculty members is available.

Payments should be made by wire transfer or check by July 1, 2015. Please make checks payable to Reservoir Engineering Research Institute and mail your payment to: RERI | 595 Lytton Ave., Suite B | Palo Alto, CA 94301 USA. To arrange a payment by a wire transfer, please email us at info@rerinst.org. Payments may be refunded upon cancellation at least 30 days prior to the beginning of the course.

To register, please complete the [online registration form](#).

Lodging

A block of rooms has been reserved at the [Pacific Euro Hotel](#):

Shared bath: \$64 + taxes and fees

Private bath: \$109 + taxes and fees

Rates are guaranteed for the nights of August 2 to August 6. Reservations will be based on availability, and should be made directly with the hotel. Please refer to the group name, *RERI*, when reserving your room.

[Pacific Euro Hotel](#)

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Public Transportation

The Pacific Euro Hotel is two cities north of Palo Alto. To plan your trip using public transportation, visit [511.org](#).