Characterizing Heavy Oils to Optimize Solvent-based Production

Professor Harvey Yarranton, University of Calgary, talked to heavyoilinfo.com about the program of the newly created NSERC Industrial Research Chair in Heavy Oil Properties and Processing.

Introduction

Dr. Yarranton is senior holder of the NSERC Industrial Research Chair (IRC) in Heavy Oil Properties and Processing. This Chair program, launched in May 2010 at the University of Calgary (UofC), is aimed at pursuing fundamental research in support of the development and operation of solvent-based processes for the recovery of in-situ heavy oil and mineable oil sands. These processes have the potential to increase recovery while reducing water usage and decreasing energy consumption. The work is focusing on developing methodologies to characterize the effects on phase behavior and fluid properties such as density, viscosity, and diffusivity, when different solvents are added to heavy oil. It is expected that the knowledge gained will improve the simulation of heavy oil behavior, both within a producing reservoir and during the refining process.

The heavy oil production industry is now getting more serious about knowing what will happen when solvents (e.g. CO_2, propane, or other alkanes) are put underground. The key variables are pressure, temperature, and composition.

Characterization challenges

Currently available simulation software systems can cater for most of the changing behavior of conventional oils using characterizations constructed from gas chromatography (GC) and distillation analyses; however, heavy oils contain a higher proportion of non-distillable fractions, for which it is much more difficult to calculate boiling-point curves. Typically, curves exist for characterizing the behavior of about 80% of the content of conventional oil. By contrast, less than 50% of heavy oils can normally be characterized by distillation-based methods of calculating boiling-point curves. At present, the behavior of the non-distillable fractions must be extrapolated from the distillable fractions, and the validity of such extrapolations is questionable.

Data for the non-distillable fractions cannot be measured directly because these fractions react at around 300-340 degC through thermal decomposition; breaking down into coke and various gases. Few tools currently exist to characterize many heavy oil fractions. SARA (saturate, aromatic, resin, asphaltene) analysis is too crude, partly because differentiating between aromatics and resins is rather arbitrary.

Deep vacuum analysis can extend the range of PVT measurements that can be made through distillation analysis. Yarranton plans to use equipment capable of vacuums down to one millionth (10**-5 kpa) of atmospheric pressure. Boiling points reduce at lower pressures, extending the limits of the laboratory equipment and avoiding the thermal decomposition of some heavy oil fractions, because the temperature of such decomposition remains relatively unchanged with decreased pressure. The same equipment can be used to measure vapor pressures for heavy oil fractions obtained with other methods.

Simulation challenges

Once characterization data are available, it remains a challenge to predict the phase behavior and physical properties of heavy oil and solvent mixtures because the available data and correlations are not necessarily applicable. A key objective of the Chair program is to develop an equation-of-state based methodology to predict both conventional vapor-liquid equilibria as well as asphaltene precipitation. Asphaltenes can precipitate upon a change in temperature, pressure or composition and are particularly difficult to model. Another objective of the program is to develop properties correlations such as critical properties, density, viscosity, and diffusivity that are consistent with the equation of state methodology. With this methodology, the heavy oil is represented with about 20 “pseudo”-components, of which 10 will typically be distillable and 10 non-distillable. The chair program will focus on assigning properties to the non-distillable components and developing mixing rules for the equation of state model.

Yarranton says that his group wants to take a lot of different heavy oil samples and then “beat them to death” with existing and new methods of characterization, make correlations based on these methods, and test the predictions. The objective is to extend the knowledge of the phase behavior and physical properties of heavy oils. The ultimate target is to find ways to produce heavy oil more efficiently and with less environmental impact.

The project team

Yarranton’s team includes 2 staff responsible for looking after the laboratories and training students in using the equipment. The work itself will largely be performed by PhD and Masters’ students, each working on different projects within an overall framework defined by Yarranton and his industry advisors, who are principally from Shell and Schlumberger. Various elements of the work will be supported by other members of the Chemical & Petroleum Engineering department, plus experts from other departments of the UofC. These local experts include Professor Marco Satyro, who is also CEO of Virtual Materials Group Inc., a company that develops software to design and optimize a range of chemical processing systems.

Several oil companies have been interested in the composition and behavior of heavy oil for a long time, but in the last 10 years there has been growing interest in their behavior when combined with solvents. Solvents—perhaps in conjunction with steam—may help production from heavy oil reservoirs with reduced input energy relative to purely thermal methods.

Solvents might also be effective in reservoirs that are unsuitable for thermal methods, for example because they are too thin or too shallow. The Chair program is aimed at helping companies to determine when solvents might help and selecting appropriate materials to inject.

5-year program phases

Heavy oil characterization is a large area of work, with room for a lot of people to get involved, such as Professor John Shaw of the University of Alberta. The new Chair at UofC is not the beginning of the project; but rather the continuation of a consortium, supported by some of the sponsors of the Chair, that has been running for about 5 years. The program will focus and build on previous work, as well as developing novel approaches. Yarranton hopes to have the heavy oil modeling framework ready by the end of the first 5-year phase of the Chair program. This will provide the framework for extending the project, for example, adding steam, and investigating possibilities to extend the capabilities of simulators to look at multiple phases and their impact on permeability. There is also interest in water/oil interactions and the behavior of emulsions. The results of the work will not only apply to oil production, but will also be valuable for modeling behavior in refineries, pipelines and other more downstream facilities.

About Harvey Yarranton

Harvey Yarranton in front of a PVT laboratory testing cell.

Dr. Yarranton is a Professor in the Department of Chemical & Petroleum Engineering at the Schulich School of Engineering, University of Calgary. He received a B.Sc. in 1985 and a Ph.D. in 1997, both from the University of Alberta, Edmonton, Canada. Between 1985 and 1993 he was a Senior Petroleum Engineer with Amoco Canada Petroleum Co. Ltd. and Dome Petroleum Ltd.

He became the senior holder of the NSERC Industrial Research Chair in Heavy Oil Properties and Processing in 2010.

Dr. Yarranton's research interests are in the general areas of interfacial science and thermodynamics applied to bitumen and heavy oil production and processing. Current and past research projects in these areas include:

- heavy oil properties and phase behavior
- asphaltene molecular self-association
- asphaltene precipitation
- asphaltene particle aggregation
- asphaltene deposition
- the role of oil constituents in stabilizing water-in-oil emulsions
- solids-stabilized emulsions
- treatment of water-in-heavy oil emulsions
- bitumen extraction and froth treatment and rag layer formation during emulsion separation