



Bitumen and Heavy Oil Research Program



Updated 2009-2010

About STEPS: Since 1998, the Petroleum Technology Research Centre has managed its Enhanced Oil Recovery (EOR) research program, providing leading-edge technology and innovation for our public and private sector partners. In January of 2009, that research excellence was acknowledged when the Government of Canada, through its Business-Led Networks of Centres of Excellence program awarded the PTRC \$10.5 million over four years to expand and enhance its existing EOR program. The Saskatchewan Government also increased its already substantial, on-going financial support, and along with continued private sector sponsorship the “Sustainable Technologies for Energy Production Systems” or STEPS BL-NCE was born.

Goals: The STEPS Network aims to become the national focus for leading-edge scientific and engineering innovations that address hydrocarbon energy production challenges for resources that are difficult to access. This includes research in three hydrocarbon areas:

- Proven economic resources such as bitumen and heavy oil, including up to 80% of the resource that is currently difficult to access because of location, depth or geology;
- Future hydrocarbon resources such as oil shales and deep unmineable coal seams, and developing enabling technologies to access such resources;
- Light-medium conventional oil, particularly reserves that are in decline and need new technologies to improve recovery.

Developing energy synergies between industries will also be investigated.

Structure: The PTRC is a non-profit company that manages the STEPS Network. It directs and shapes research in the three areas above through industry-dominated Technical Advisory Groups to which projects are submitted via requests for proposals each year. Industry eligibility in these TAGs is determined by financial sponsorship of STEPS research. With the PTRC’s guidance, proposals are prepared, ranked and selected to form the research programs in each of the three areas. The projects listed in this brochure are only for the initial bitumen and heavy oil area. The other areas are currently being developed.



Bart Schnell, Senior Research Technologist at Saskatchewan Research Council, works on the 3D physical model during SVX experiments.

Bitumen and Heavy Oil Program: Focus Areas

1. Heavy Oil (Post) Cold Production

STEPS is working with operators to optimize cold production itself and to extend reservoir life by developing *post-cold-production* techniques. Follow-up methods can both exploit and remedy the condition of the depleted reservoir (i.e., the presence of wormhole channels caused by sand production).

2. Enhanced Waterflooding

When the effectiveness of primary production wanes, operators often opt for waterflooding. However, many waterfloods have reached an economic limit and need enhancement such as chemical addition to alter the water’s interaction with the oil. Though waterflooding is popular, little is understood about its physical and chemical mechanisms. Waterflooding of heavy oils—a practice nearly unique to western Canada—differs markedly from that of lighter oils.

3. Solvent Vapour Extraction (SVX)

STEPS is proving SVX as a viable, low-cost, low-energy EOR technology. SVX is a family of methods in which gaseous solvents (e.g., CO₂, propane or butane) are injected into an oil reservoir to dilute oil and drive it towards production wells. Although initially aimed at thinner-pay-zone heavy oil reservoirs, SVX is expected to compete well with thermal methods such as steam-assisted gravity drainage in thicker heavy oil or medium oil reservoirs.

4. Gas Flooding (Miscible/Immiscible)

The long-standing, broad expertise of PTRC’s research partners in gas flooding technology includes miscible CO₂ injection in southeast Saskatchewan, conversion of miscible hydrocarbon floods to CO₂ flooding in Alberta, and immiscible injection of CO₂ and flue gas in Lloydminster-area heavy oil reservoirs. Projects in this area emphasize understanding the mechanisms of gas flooding, reducing its cost, and increasing its applicability.

5. Improving Heavy Oil Predictability

Correlations that predict oil properties such as solvent solubility and the resulting viscosity and density for conventional oils will often just not work well with heavy oils. The knowledge developed in this area will allow engineers to predict the outcomes of heavy oil field projects with greater confidence.

6. Oil Sands and Bitumen: Characterization of Deposits, In-situ Technology Improvement and Field Trials

STEPS is extending its research to include developing new technologies, and adapting existing ones, to meet the challenge of in-situ recovery of oil sands deposits that are not currently accessible. This broad program of R&D requires understanding and characterizing Saskatchewan’s oil sands resource, and investigating technologies that could be used where the shallowness of the resource, or a lack of caprock, make existing technologies such as SAGD ineffective. Proposals for the 2010-2011 fiscal year are currently in review.

SUMMARIES OF SOME CURRENT PROJECTS

Heavy Oil Cold Production Optimization

The main objectives of this research project are to understand the critical effects of wormhole structures on primary cold production and post cold production. In turn, this will help optimize the field operation and cold production system so as to improve the recovery of heavy oil, and to suggest infill drilling locations. The project will evaluate CHOPS well performance, and support decision-making during post cold production processes.

G. Zhao, University of Regina

Cyclic Solvent Stimulation for Cold Produced Reservoirs

This project is aimed at providing more accurate simulation of the cyclic solvent stimulation process for cold-produced reservoirs (oilfields in which sand was deliberately co-produced with the oil, creating high-permeability channels called wormholes). SRC's multi-well cold production numerical model will be modified to better simulate the direction in which wormholes grow in such reservoirs. The proximity of wormhole networks that develop from each cold production well influences the sweep efficiency of the solvent in cyclic solvent injection processes. Once the model is improved, it will be used to investigate the effect of the solvent type (CO₂/propane or methane/propane) on the process.

B. Tremblay, SRC

Utilization of CO₂ for Pressure Maintenance and Improving Oil Recovery from Heavy Oil Reservoirs

Pressure maintenance through gas injection has been implemented for light oil reservoirs for many years, but the suitability of CO₂ for this purpose in heavy oil reservoirs has not been investigated. This proposal aims at conducting a comprehensive study, both experimentally and through simulation scenarios, for utilizing CO₂ for pressure maintenance in heavy oil reservoirs. *D. (Tony) Yang, University of Regina*

Optimized Surfactant-Polymer Waterflooding for Heavy Oils

This study aims to demonstrate the feasibility of the surfactant-polymer flooding technique for enhanced heavy oil recovery. Several important properties of the chemical solution in contact with the heavy oil (interfacial tension, viscosity, ability to form emulsions, and long-term stability) will be evaluated. A chemical mixture that tolerates high salinity and hardness will be designed that can minimize polymer degradation, chemical adsorption, and viscous fingering. Coreflood tests will then be conducted using the optimized chemical mixture. *M. Luo, SRC*

2D Model Study of Chemical Flooding

This project is to develop a process of enhanced heavy oil recovery by chemical flooding. On the basis of previous research results, 2D physical model tests and a scale up study will be conducted. This project will produce the chemical formulas for improving sweep efficiency and enhanced oil recovery by chemical flooding, and

Post-Cold Production EOR: Air Injection Pilot Preparations

This multi-year project is devoted to a new air-injection process for heavy oil fields that have matured under cold production with sand. A renewed effort will be made to establish a producer consortium to prepare for implementing a field pilot. Meanwhile, the accompanying goal of reliable simulation methods for air injection will be advanced through laboratory kinetics tests to the point where genuine prediction of combustion front stability may become possible. In addition, pilot operating conditions will be screened with the use of a recently developed simulation model that incorporates wormholes from cold production. *N. Freitag, SRC*



Dr. Norm Freitag of SRC works with principal research technologist Ray Exelby on a PVT apparatus

Pyrolysis Kinetics of Low-Temperature Oxidation Residues from Heavy Oil Reservoirs

This project will determine the reaction kinetics for the pyrolysis of LTO residues formed by heavy oil and incorporate this into an overall reaction model to be assessed in numerical simulations of an air injection process. It offers a fundamental study of multi-phase flow at high temperatures during an air-injection process. *N. Mahinpey, University of Calgary*

develop injection strategies. It will scale up parameters for heavy oil recovery by chemical flooding and provide a field scale prediction of oil recovery by chemical flooding. *M. Dong, University of Calgary*

Optimizing Regime-Based Waterflooding for Heavy Oil Waterfloods

This project continues SRC's statistical work on heavy oil waterfloods, with a new focus on determining best operating practices at different time stages of the floods. These stages are classified by their flow regimes: (I) oil only; (II) mostly oil; (III) water-in-oil emulsions; and finally (IV) water dragging clumps of emulsions. Other researchers consider Regime III to be the most productive waterflood period, but SRC's ongoing statistical studies suggest that Regime IV may perform better. We will examine the factors that separately contribute to success during Regimes III and IV. *G. Renouf, SRC*

Success of Heavy Oil Waterfloods - Factors and Predictions: Development of Neural Networks Tools

This project aims to complete a comprehensive study on developing and testing a current neural networks model for predicting the performance of waterflooding of heavy oil reservoirs. This will be done by evaluating the effect of a variety of field information on the outcome of this model. The project will incorporate additional geological data in the model. *F. Torabi, University of Regina*

Improving Conformance Control Technologies

Conformance control applications using polymers and polymer gels can improve poor production in a variety of conventional and

heavy oil reservoirs. Excessive water cuts and even well abandonment can result from unfavourable water/oil mobility ratios and/or severe heterogeneities (fractures, wormholes). This project will address the effects of brine salinity and divalent ion content as well as polymer shear history on polymer adsorption on unconsolidated heavy oil reservoir sands. Polymer gel injection patterns and the effects of gel volume and shear history on gel performance will be evaluated using a 3D physical model with a vertical injection well. In both cases, numerical simulation will be used to history match the laboratory experiments. *M. Luo, R. Wilton, SRC*

Numerical Simulation of SVX Processes

This project includes extensive numerical simulation studies using previous 3D physical modelling data sets to improve numerical simulations of the SVX processes by better representing the three most important physical parameters: relative permeability curves, total effective solvent mass transfer, and non-equilibrium solvent solubility. This work will build on previous simulation studies, and introduce a novel history-matching approach using a non-equilibrium solvent solubility parameter derived from experimental data. *K. Knorr, SRC*

Asphaltene Precipitation and Its Effects on CO₂-Enhanced Heavy Oil Recovery

When CO₂ contacts heavy oil at certain pressures and temperatures, asphaltene precipitation occurs; the heavy oil in the reservoir is in-situ de-asphalted. Meanwhile, some precipitated asphaltenes may get deposited onto the reservoir sand grains and, thus, reservoir permeability is significantly reduced. Since CO₂-induced asphaltenes can be rather different from those induced by light hydrocarbons, this project will not only study the beneficial and detrimental effects of asphaltene precipitation and deposition on CO₂-enhanced heavy oil recovery but also analyze the physicochemical properties of CO₂-induced asphaltenes from crude oil samples under different experimental and heavy oil reservoir conditions. *Y. (Peter) Gu, University of Regina*

Evaluation of Solvent Vapour Extraction (SVX) Processes Using a 3D Physical Model

SVX processes offer an attractive alternative to thermal methods because they use less energy and water, avoid CO₂ production, and are more suitable for thinner, shallower, or partially depleted reservoirs. This study includes one experiment in SRC's 3D physical model, field scaling, and numerical simulations. It will determine the dependence of oil production rates and recovery on the combined effects of the solvent mass transfer rate and solubility by reducing the solvent injection rate while maintaining the total injected solvent mass. The results will be compared to a previous baseline run. *K. Knorr, SRC*

Asphaltene Precipitation and Its Effects on the SVX Heavy Oil Recovery Process

When a solvent is in contact with heavy oil at high reservoir pressures during solvent vapour extraction, asphaltene precipitation occurs. The heavy oil in the reservoir is in-situ upgraded. Meanwhile, some asphaltenes may be deposited onto the reservoir sand grains and, thus, the reservoir permeability is reduced. Among the most important factors in precipitation are the operating pressures, reservoir permeability, solvent type and oil composition. This project will study asphaltene precipitation and deposition, and examine their beneficial (i.e., in-situ upgrading) and adverse (i.e., reservoir plugging) effects on SVX. *Y. (Peter) Gu, University of Regina*

Solvent Dispersion Effect on the SVX Heavy Oil Recovery Process

When a solvent is injected into a heavy oil reservoir, significant heavy oil viscosity reduction is achieved through solvent dissolution (molecular diffusion and convective dispersion). In particular, solvent dispersion may greatly accelerate the solvent dissolution into heavy oil during solvent vapour extraction. This is a key technical issue to be addressed in depth. In practice, it has been found that solvent dispersion is strongly affected by several important operational factors, such as solvent type, solvent injection conditions, horizontal well spacing and configuration, and reservoir characteristics. This project will examine the detailed effects of these factors on heavy oil and solvent production rates. A novel theoretical model will be developed to predict heavy oil production during the SVX process. *Y. (Peter) Gu, University of Regina*

Underground Sonar for Detecting the Growth of the Chamber in SVX Processes

This project aims at utilizing acoustic sonar for detecting the shape of the vapour chamber in the SVX processes. An experimental set up has been designed and digital signal processing algorithms have been developed and tested to help determine the shape and size of the vapour chamber in an environment of water-saturated sand. Currently, experiments in an oil environment are underway. *R. Paranjape, University of Regina*

Maximizing the Performance of Immiscible Gas Flooding in Heavy Oil Reservoirs

This research is aimed at optimizing immiscible gas flooding for heavy oils through improvements to displacement efficiency and reduction in oil viscosity. A comprehensive review will be conducted of SRC's previous research results for immiscible gas coreflooding with a variety of heavy oils and gases. Based on previous years' results, more solvents will be tested including CO₂ to find the most economical and effective injected solvents in gas flooding. In coreflood tests, various factors – slug size, injection rate, and injection scheme – will be evaluated to improve displacement efficiency. *M. Luo, SRC*

Phase Behaviour of Solvent(s)-CO₂-Heavy Oil Systems under Subcritical and Supercritical Conditions

Conventional thermal methods often do not work for recovering heavy oil in thin reservoirs; CO₂ injection may recover additional oil through an immiscible process. Addition of solvents to a CO₂ stream will generally accelerate the process of swelling the oil and reducing its viscosity, and thus achieve higher oil recovery. This

project will study phase behaviour of the solvent(s)-CO₂-heavy oil system under subcritical and supercritical conditions and subsequently determine the potential of CO₂-gaseous solvent mixtures for increasing oil recovery for thin heavy oil reservoirs. *D. (Tony) Yang, University of Regina*

Investigation of Two- and Three-Phase Relative Permeability

This project will investigate the 3-phase relative permeability relation for CO₂-oil-water systems through a series of carefully designed laboratory experiments. It is expected that the outcome of this research will enrich our fundamental understanding of the flow of CO₂ in oil reservoirs in the presence of both water and oil. In addition, the scientific findings will be of great benefit to oil companies that are interested in CO₂ flooding for reservoirs. *F. Torabi, University of Regina*

Three Phase Relative Permeability for Heavy Oil Systems

This project aims at experimental measurement and mathematical development of two- and three-phase relative permeability during multiphase flow of fluids in a porous media containing heavy oil, water and solvent. Two- and three-phase relative permeability are key parameters for both history matching and future forecasting of most recovery processes at experimental and field scales. The effect of parameters such as oil viscosity, temperature, and rock wettability on three-phase relative permeability will be evaluated. Results obtained will then be used to develop a series of correlations that can predict the relative permeability trends for systems containing heavy oil. *F. Torabi, University of Regina*

Solubility and Diffusion Coefficients of Gases in SARA Fractions and Heavy Oils

In this project, the solubility and diffusion coefficients of carbon dioxide, ethane and propane will be measured for several western Canadian heavy oils and their SARA fractions. A gravimetric microbalance will be used for pressures up to 2 MPa, and equation of state and Solubility Parameter Theory models will correlate and predict the solubility data. Determining the solubilities of oils is critical to helping companies understand the amount and type of solvents to use in reservoirs, to help optimize recovery rates. *E. Shirif, A. Hemi, University of Regina*

Improved Recovery for Heavy Oil Reservoirs Using Simultaneous Thermal and Chemical Flooding

This project will develop a process for enhanced heavy oil recovery using simultaneous injection of chemicals/thermal flooding. In the proposed process, thermal/chemical floods will be used to improve sweep efficiency, and displace heavy oil out of reservoirs. Research will be conducted into chemical formulas for improving sweep efficiency and oil recovery. *E. Shirif, A. Hemi, University of Regina*

Equation-of-State Characterization of Heavy Oils

The conventional correlations of the physical properties of oils, which are mainly based on light-oil data, generally become increasingly inaccurate when heavier oils are considered. This multi-year project addresses the overall need to provide reliable heavy-oil correlations that can be trusted during numerical simulations. Current year research uses a new and promising approach for prediction across temperature differences. The test will use SARA-fraction data from the experimental side of this program. A literature search for additional improvements will be conducted, and a recently uncovered, alternative correlation for oil viscosity will be tested. *N. Freitag, SRC*

Oil Sands and Bitumen Research

STEPS is expanding to include projects that address improvements to existing in-situ bitumen recovery technologies, or that develop new technologies to make currently inaccessible oil sands (i.e. deposits that lack caprock to contain heat during SAGD operations) accessible. Research will also include technologies with the potential to reduce the environmental footprint and energy use of recovery.



The PTRC is located in Regina, Saskatchewan.
Visit www.ptrc.ca for more information on STEPS,
or contact us at 306.787.7497