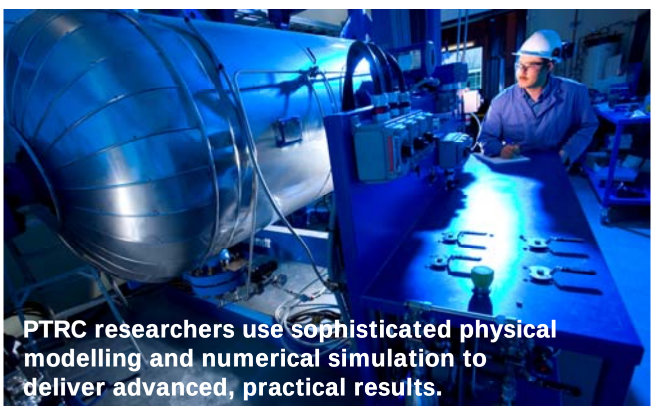
EOR Program 2008–09

Enhanced Oil Recovery Research Program

About: The Enhanced Oil Recovery (EOR) Research Program is the cornerstone of the PTRC's drive to advance innovative technologies with a bigger impact and smaller footprint than current practices. Starting with concept development and progressing to full field deployment, the EOR Research Program is a seedbed for new ideas with the potential to transform how effectively and sustainably oil is recovered, in Canada and beyond.

Goals: The EOR Research Program aims at developing leading technologies for economic enhanced oil recovery, with an eye to environmental sensitivity. Practical application—new technology and knowledge that can be taken from the laboratory and deployed in the field—is a hallmark of our approach.

Structure: The PTRC, a non-profit organization, solicits the advice of industry to focus our research efforts for each program year. With this industry guidance, proposals are prepared, ranked and selected to form the PTRC EOR Research Program. The projects are carried out by research organizations, mainly the Saskatchewan Research Council (SRC) and the University of Regina (U of R).



PTRC researchers use sophisticated physical modelling and numerical simulation to deliver advanced, practical results.

The EOR Research Program's 5 Focus Areas

The EOR Research Program supports projects that fall mainly under the following five areas of EOR:

1. Heavy Oil (Post) Cold Production

This method employs progressive cavity pumps to co-produce heavy oil and sand, maximizing recovery before enhanced techniques are used. However, challenging heavy oil and reservoir characteristics mean that, on average, only about 7% of the resource can be economically recovered with existing technology.

The PTRC works 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), but they require knowledge of the possible location, extent, and stability of wormholes.

2. Enhanced Waterflooding

When the effectiveness of primary production wanes, operators often opt for waterflooding to keep up production. Waterfloods can turn a profit even when the oil makes up 5% or less of the produced fluids. However, many projects have reached an economic limit and need some kind of enhancement, such as chemical addition to alter the injected water's interaction with the oil.

Though waterflooding is popular, little is understood about its physical and chemical mechanisms. The reason for a waterflood's success or failure is often not apparent. As well, waterflooding of heavy oils—a practice nearly unique to western Canada—differs markedly from that of lighter oils. It requires its own operating principles and procedures. The PTRC is shedding valuable new light on and giving new life to a tried and true technique.

3. Solvent Vapour Extraction (SVX)

The PTRC is proving SVX as a viable, low-cost, low-energy EOR technology. SVX is a family of methods in which gaseous solvents (e.g., CO_2, 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. Here, the process's environmental edge could allow it to prevail in the future.

This area dovetails with JIVE (Joint Implementation of Vapour Extraction), the PTRC's program to demonstrate SVX in field pilots.

4. Gas Flooding (Miscible / Immiscible)

The long-standing, broad expertise of PTRC's research partners in gas flooding technology includes miscible CO_2 injection in southeast Saskatchewan, conversion of miscible hydrocarbon floods to CO_2 flooding in Alberta, and immiscible injection of CO_2 and flue gas in Lloydminster-area heavy oil reservoirs. The U of R's substantial investment in CO_2 capture provides a cradle-to-grave capability.

Projects in this area emphasize understanding the mechanisms of gas flooding, reducing its cost, and increasing its applicability.

5. Improving Heavy Oil Predictability

This is a new initiative to characterize and correlate properties for heavy oils so that EOR projects can be screened accurately. 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 reservoir engineers to predict the outcomes of heavy oil field projects with greater confidence.

SUMMARIES OF PROPOSALS FOR 2008–2009

1

Scaled Physical Model of Post-Cold Production

Cyclic solvent stimulation (CSS) is currently being field tested in cold-produced reservoirs. This project seeks to provide the data and knowledge needed to guide application of this technique and to improve oil recovery predictions. Two key parameters for CSS—gas relative permeability under solution gas drive, and dispersion coefficients of the solvent into the oil—will be measured in two types of physical models. The results will be critical inputs for future numerical simulation to allow field scale-up and generalization to reservoirs with different physical properties. B. Tremblay, SRC

Multi-Well Cold Flow Model

This project will help industry participants seeking to use tighter well spacings and more infilling to recover more oil. These are limited by the advance of wormhole channels in the reservoir. SRC's predictive numerical multi-well cold production model will be tested using field production data from several wells producing simultaneously over a large area. Then the model will be used to estimate the optimal spacing and the maximum time for economical infill, and correlations will be developed for use by field engineers. B. Tremblay, SRC

Cold Flow Production Database

Which reservoir parameters and production practices affect the success of cold production rates, and to what extent? Using an approach of multivariate analysis, this project will build a database of oils pools undergoing cold production to identify the parameters that optimize cold-flow and post-cold-flow production. G. Renouf, SRC

Air Injection Pilot Preparation – Year 2

Air injection could become a viable option in thinner, cold-produced heavy oil fields and add reserves worth a billon dollars in the area around Lloydminster, Saskatchewan. This project is intended to pave the way for the development and field demonstration of the EOR method. Work will proceed along two fronts: a pilot test by a consortium of producers; and improvement of SRC's chemical reaction model and simulation procedures needed to help analyze the pilot and optimize performance in subsequent projects. N. Freitag, SRC

* Modeling and Simulation of Isothermal / Non-Isothermal Combustion Experiments

The reaction kinetics of coke combustion must be better understood for numerical simulation purposes. The thermal behaviours of Fosterton field asphaltenes, whole oil, and differently derived coke are being examined through thermogravimetric analysis. This will provide useful combustion rate data and improve understanding of in-situ combustion. The reaction kinetics of the samples and the energy of activation and pre-exponential factor will be evaluated and kinetic models proposed. N. Mahinpey, U of R

* Modified Vapex Process for Wormhole Reservoirs

The unknown nature and extent of wormhole channels in wormholed reservoirs make it hard to implement EOR processes. A modified Vapex approach is being developed that treats the reservoir as a black box; the wormholes do not need to be mapped to ensure success. The goal is achieved through simulating a wormhole environment under various production scenarios by injecting CO_2, C_1, and a C_1-C_3 mixture as solvents. As part of this work, the diffusion of these gases in oil at reservoir conditions has been measured. K. Asghari, U of R

* Gas Relative Permeability Measurements for Solution Gas Drive

This project seeks to improve the numerical simulation of primary oil recovery by incorporating relative permeability curves performed at field capillary numbers (velocities). Pressure depletion experiments—conducted at velocities spanning the range in capillary numbers calculated by the multi-well cold production model—will allow a correlation to be obtained between capillary number and relative permeability to gas for a heavy oil. B. Tremblay, SRC

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Success of Heavy Oil Waterfloods – Factors & Predictions, Phase II

SRC has conducted substantial statistical research into the reasons behind success or failure of heavy oil waterfloods. In this year, the approach of multivariate analysis will be complemented by the U of R's application of neural network modeling toward the same goal. We will examine selected waterfloods in the database with respect to different periods in their lifespan as various operating strategies are pursued. As well, we will investigate complex injection patterns and timing of waterflood start, and further study the role of in-situ emulsions. G. Renouf, SRC; K. Asghari, U of R

Improved Waterflooding of Heavy Oil

The fundamental mechanisms of heavy oil waterflooding are not understood well enough to ensure successful application. Evidence is also mounting that conventional recovery theory may not apply to heavy oil waterfloods. In this year of the study, we will examine the effect on heavy oil recovery of wettability, pore shape, and initial water saturation in micromodel flow tests. Our look at CO_2-assisted waterflooding will focus on optimizing the CO_2 slug size and the soak period in corefloods, micromodel runs, and numerical simulation. C. Jackson, SRC; K. Asghari, U of R

Waterflood Additives for Improved Heavy Oil Recovery – Year 2

This project will identify and test cost-effective additives (polymer for mobility control, and surfactants for interfacial tension reduction) that can improve the sweep efficiency of injected water and improve the recovery factor of heavy oil waterfloods. This year's research will examine in-situ generation and dispersion of oil-in-water emulsions under reservoir conditions, and emulsion behaviour in newly designed radial coreflood equipment that is expected to better represent actual flow mechanisms than linear coreflood testing. P. Zhang, SRC

* Projects marked with an asterisk are ongoing, multi-year projects. Participation in these may be negotiated on a project-by-project basis.

Improving Conformance Control Technologies – A Fundamental Approach

Conformance control methods using polymers can be applied to a variety of conventional and heavy oil reservoirs that have poor production due to significant heterogeneities (fractures, wormholes) and/or unfavourable mobility ratios between flood and resident fluids. This research will address the shortcomings of these technologies by investigating mechanisms to increase the polymer stability and overall performance in these environments. Experiments will focus on the polymer cohesive strength with reservoir sands, polymer adsorption and permeability reduction, and techniques to strengthen the polymer/gel/sand interface. R. Wilton, SRC

* Simulation of EOR by Chemical Flooding

The project incorporates fundamental theories and models developed in previous projects into numerical reservoir simulation for designing and predicting the field performance of enhanced waterfloods by chemical flooding. Various chemical and interfacial property models are being created. Further laboratory work will examine the flow behavior of emulsions in porous sandpacks. History matching and analysis will be used to verify and modify the models. M. Dong, U of R (now at U of Calgary)

Low Cost Chemicals for Enhanced Waterflooding

Alkali is a key but often costly component of chemical flooding. A 2004 PTRC study found that it was ten times cheaper to clean and transport sodium carbonate sourced from smelt (a pulp and paper residue) than to use sodium hydroxide as the caustic. This research will focus on inexpensive upgrading of sodium carbonate by converting its sulfides to sulfates; oxidation methods such as wet air, peroxide, ozonation, and ultraviolet enhancement will be tested. The upgraded alkali will be evaluated in a coreflood. C. Jackson, SRC

* Dispersion-Alternating-Displacement Technique for Heavy Oil Recovery by Alkaline Flooding

An innovative EOR process is being developed with the following advantages: in-situ water-in-oil dispersion effectively increases water flow resistance in water channels to improve sweep efficiency, and in-situ oil-in-water emulsions use water to entrain and displace heavy oil out of oil sands. Key results include optimal chemical formulas, injection strategies, a method to treat divalent ions of the injection water for field application, and a method of treating produced oil-in-water emulsions. M. Dong, U of R (now at U of Calgary)

Evaluation of Solvent Vapour Extraction (SVX) Processes – Year 4

Testing of SVX processes has shown their potential for very high heavy oil recovery factors with high solvent recycle rates. This project extends our effort, using both a high-pressure 3D scaled physical model and numerical simulation, to examine the important oil production rate and recovery mechanisms acting during SVX processes. These mechanisms, particularly the solvent-to-oil mass transfer dispersivity, will be incorporated into numerical simulation models. The ultimate goal is to provide a predictive modeling tool for the field application of SVX. K. Knorr, SRC

Underground Sonar for Detecting the Growth of Vapex Chamber in Vapex Process

The ability to monitor the shape and growth of the vapour chamber during a Vapex process would be invaluable. It would provide essential information about the effectiveness of the process in the field, about the volume of residual oil, and about the validity of various models for predicting the Vapex production rate. Based on the U of R's existing expertise in sonar detection, this project aims at developing an innovative, laboratory-scale underground sonar technique for detecting the size and shape of vapour chambers in unconsolidated sand environments. K. Asghari, R. Paranjape, U of R

* Phase Separation of a Solvent-Saturated Heavy Oil during Solvent-Based HO Recovery Processes

Solvent-based processes are promising heavy oil recovery techniques. The physical and chemical properties of a solvent-saturated heavy oil will change dramatically after its phase separation occurs. This project's extensive experimental studies and thermodynamic modelling are aimed at quantifying these property changes and detailing their effects on solvent-based heavy oil recovery. Y. Gu, U of R

* Solvent Dispersion Effect on Vapex Heavy Oil Recovery Process

In solvent-based processes, solvent dispersion may greatly accelerate its dissolution into the heavy oil. This dispersion is strongly affected by several operational factors, e.g., solvent type and injection conditions, horizontal well spacing and configuration, and reservoir characteristics. The effects of these factors on heavy oil and solvent production rates are being studied physically and numerically, and a novel theoretical model is being developed to predict heavy oil production during solvent vapour extraction. Y. Gu, U of R

* Asphaltene Precipitation and its Effects on the Vapex Heavy Oil Recovery Process

When a solvent contacts heavy oil at high reservoir pressure during solvent vapour extraction, asphaltene precipitation occurs so that the heavy oil is upgraded in situ. As well, some asphaltene deposition may occur in the reservoir, reducing its permeability. Key factors include operating pressure, reservoir permeability, solvent type, and oil composition. This project is studying both the beneficial and adverse effects of this precipitation. Y. Gu, U of R

* Horizontal Well Testing in Heavy Oil Reservoirs for Estimating Chamber Size for Vapex and SAGD Processes

The swept volume in SAGD (steam-assisted gravity drainage) and Vapex is an early measure of their progress. The pressure analysis of the falloff test—used to estimate swept volume for vertical wells—is based on the pseudosteady state method. The accuracy and applicability of this method to estimate swept volume for fluid injection through a horizontal well is being studied. Numerical simulation will generate pressure falloff data, and a simple correlation for estimating chamber volumes for SAGD/Vapex will be developed. E. Shirif, U of R

Optimal Solvent Properties to Create Maximum Efficiency in Immiscible Gas Flood for Improved Heavy Oil Recovery – Year 2

An enriched flue gas was found to work as well as pure CO_2 in recovering heavy oil in immiscible gas injection in pressure-depleted reservoirs. There may be an ideal gaseous solvent composition and/or injection sequence that leads to synergy among the specific mechanisms supplied by different gases and thereby maximizes oil recovery efficiency and operational cost-effectiveness. This year we will study different gases and gas mixtures (CO_2, C_3, enriched flue gas) in phase behaviour and coreflood tests and numerically simulate the range of reservoir properties for which immiscible gas injection could be beneficial. P. Zhang, SRC

Coupling Gas and Polymer Injection to Improve Heavy Oil Recovery – Year 2

The primary mechanisms of immiscible gas flooding for heavy oil—viscosity reduction and oil swelling—provide only modestly improved oil recovery. Gas breakthrough and fingering hamper the process effectiveness. Our Year 1 results suggest that using a polymer to augment the water in a water-alternating-gas injection scenario will greatly improve mobility ratios for both injected water and gas. The polymer not only improves sweep efficiency but also acts as a blocking/diverting agent. This year's research will focus on reducing polymer cost through selecting proper polymers and optimizing polymer concentration, slug size and injection sequence. P. Zhang, SRC

* Integrated Optimization of Displacement Efficiency in a CO_2 Flooded Reservoir under Uncertainty

In CO_2 injection, displacement efficiency needs to be optimized to achieve high oil recovery, but this remains a challenge in the presence of physical and/or financial uncertainties. This project aims to provide a pragmatic approach, technical support for industry, and theoretical models for optimizing reservoir performance in a CO_2-flooded reservoir under uncertainty. T. Yang, U of R

Equation of State Characterization of Heavy Oils – Year 2

The compositional changes that occur to heavy oil in certain EOR methods greatly affect the process success, yet remain poorly understood. This project's goal is ultimately to optimize field operations by improving the quality and reliability of numerical simulation of these EOR methods. Correlation of heavy oil properties with methods developed for light oil does not work well. Benefiting from SRC's substantial expertise in heavy oil property measurement and SARA analysis, this research seeks to provide industry with new and effective ways to predict/simulate heavy oil properties. N. Freitag, SRC

Solubility and Diffusion Coefficients of Gases in SARA Fractions

This project will provide critical data for assessing and modelling CO_2/miscible gas injection and Vapex projects. The solubility and the diffusion coefficients of light gases (CO_2, methane, ethane) will be measured in saturates, aromatics, and toluene-diluted resins and asphaltenes, and in whole heavy oil. The data will also help to develop/validate new thermodynamic models for clients interested in reservoir simulation. Our state-of-the-art microbalance can handle small samples and a wide range of temperatures and pressures up to 20 MPa. The methodology used can be applied to measuring gas adsorption in the reservoir (mass balance verification). A. Henni, U of R

* PVT and Viscosity Modelling of Gas- or Liquid-Diluted Heavy Oils

Viscosity and density predictions are critical for the production and transportation of heavy oil and gas. Gas solubility properties will be modeled using friction theory, and the results used to predict the onset of asphaltene precipitation with/without dilution in other hydrocarbons. A modified solution theory will be used to predict gas solubility in heavy oil mixtures, using available solubility data of different gases. Physical and transport properties of heavy oils, including viscosity, will be predicted using the friction theory, empirical, and semi-empirical models. A. Henni, U of R

OTHER PROJECTS OPEN FOR PARTICIPATION

Low Cost Instrumentation for Oil Fields

The performance and lifetime productivity of oilfield assets (e.g., wells, pumps) would be enhanced by the ability to continuously monitor and control the key variables of each producing component. This is especially true for marginal wells. This project is developing new low-cost transducers and sensors to obtain a wide variety of production and performance data. In the near term, we will demonstrate two instruments—a flowrate/watercut meter and an electronic tank level monitor—at a producing well in southeast Saskatchewan. We will also determine the feasibility of and most suitable method for long-term wireless downhole communications in a producing oil well to enable better understanding of how production practices affect reservoir conditions. K. Runtz, T. Conroy, U of R

Intelligent Motor Drive

This project will develop a smart microprocessor-controlled drive for an innovative DC wellhead motor currently being tested by a collaborator. This motor (DC rather than AC) is slower and higher torque than those currently used, allowing for variable speed that could be matched to the changing conditions of a well. A sophisticated drive is needed and will provide the added benefits of data storage and data analysis capability, which could reduce downtime and maintenance. The ultimate goal of this work is to enable the manufacture of these drives in Saskatchewan. R. Palmer, U of R

The PTRC is located in Regina, Saskatchewan, Canada. Visit www.ptrc.ca for more information.