



The Latest

from the
Petroleum Technology
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in innovation for the oilpatch

PTRC Pumped About New Projects

Executive Director Mike Monea scans the PTRC horizon

I am delighted to tell you about the recent progress in two of the PTRC's large research programs: the Joint Implementation of Vapour Extraction (JIVE) Program and the Weyburn CO₂ Monitoring and Storage Project, Final Phase. We've done the behind-the-scenes work of establishing the structures and assembling the funding to enable the nuts and bolts research to roll ahead.

JIVE revolves around three industry-led pilots to demonstrate solvent vapour extraction, a sustainable, potentially highly effective enhanced recovery technology for heavy oil. The program, focused on these western Canadian pilots conducted by Canadian Natural Resources Ltd., Husky Energy, and Nexen Inc., is fully subscribed. (In fact, there is such interest that a subsequent program to prove solvent vapour extraction in other regions could well be warranted.)

The federal government is on board JIVE with \$3.7 million through Sustainable Development Technology Canada (SDTC). The Government of Saskatchewan is combing its current budget for funding dollars. Full membership from sponsors is anticipated to be in place by February 15. Then the real work begins! A steering/project selection committee will be set up and start reviewing proposal submissions, which we envision will feature productive collaboration among the Saskatchewan and Alberta Research Councils and the University of Regina.

The highlights of the Weyburn CO₂ Project are the revamped management structure within the Executive Committee and the calibre of the people who will be guiding this multi-year, multi-million-dollar final phase. They include Dr. Carolyn Preston as Project Integrator. She has been seconded from CANMET (Natural Resources Canada) to mesh the technical and non-technical (policy, regulations, communications) aspects of the project. Don Seeberger, of ChevronTexaco, will chair the Steering Committee, which sets the research program and approves budgets and publications. In this role, he'll be well placed to provide tremendous insight into the needs and priorities of industry. The Executive Committee itself



PTRC Executive Director
Michael Monea

Cont'd on p. 2

PTRC Project Update

Core Area 1:

Heavy Oil Cold Flow

Wormhole Reservoir Characterization

To estimate the oil recovered by post-cold production, it is important to characterize the initial conditions of the wormholed reservoirs. This includes estimating the structure of the wormhole network, the diameter of the open channels, the pressure, and the water and gas saturation distributions within the reservoir after cold production.

Most of the effort so far has dealt with modeling the development of wormholes from initial perforations in a vertical well using a fine grid. These simulations show that wormholes grow out into the formations along the higher permeability layer. The number of these wormholes is significantly less than the number of initial perforations for a typical vertical permeability profile. **Project Leader:** Bernard Tremblay, tremblay@src.sk.ca.

Multi-Well Cold Production Predictive Numerical Model

The objective of this project is to develop a multi-well cold production model that can be used to estimate oil reserves, infill drilling schedules, watering-out potential and optimum water shut-off strategies. As an initial approach, the number of wormholes which develop from each well was estimated based on the produced sand volumes. A multi-well cold production model has been developed for two-phase (oil and gas) flow. The model is being tested using field data. **Project Leader:** Bernard Tremblay, tremblay@src.sk.ca.

Wormhole Stability to Solvents and Steam

This project's aim is to study the stability and permeability of wormholes during solvent injection for post-cold production recovery of heavy oils in western Canada. A wormhole stability experiment was performed in which butane gas was injected into an open channel (10-cm-dia.) at a pressure below its dew point. When the pressure in the sand pack was increased to the dew point pressure, the sand above the channel caved in. A series of shear bands above the wormhole could be observed. The permeability of the sections of collapsed

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PTRC Pumped

Cont'd from p. 1

will be chaired by Floyd Wist, a director within Saskatchewan Industry and Resources and another long-time champion of the PTRC. We are very excited by the prospect of working with these key individuals.

The Core R&D Program is close to wrapping up its fiscal year; the items in this edition of The Latest report on the most recent progress. We continue to implement a more formal, industry-responsive structure in this program. A Technical Advisory Group comprising members from industry and government is charged with reviewing proposals for projects to be implemented by the PTRC. Other elements being adopted or honed include quarterly reporting, biannual seminars for industry, and a new database populated by projects and available to industry participants and advisory groups.

On a more personal note, I'd like to recognize the legacy of the late Larry Spannier in building the PTRC. Larry—who passed away suddenly January 29—was Deputy Minister of Saskatchewan Industry and Resources (SIR) before recently being named Senior Vice-President of Crown Investment Corporation of Saskatchewan. We enjoyed a great working relationship with Larry during his tenure at SIR. He was extremely supportive of our efforts and understood the value of the PTRC's big projects like JIVE and Weyburn. What's more, he successfully communicated to government and industry the financial benefits that the PTRC could bring to Saskatchewan. Because his views held a lot of weight, Larry was integral to building the necessary sponsor teams for Weyburn. His influence will be felt for years to come as we progress on these ventures. We extend our deepest condolences to his wife, Sandra, and his daughters, Kathryn and Heather.

Your feedback is welcomed! Please contact me at michael.monea@ptrc.ca.

sand was the same as that of the intact sand. **Project Leader:** Bernard Tremblay, tremblay@src.sk.ca.

Drilling through Wormholed Reservoirs

Conventional fluid-loss reducers have so far not been successful in horizontal well drilling through wormholed reservoirs. The purpose of this project was to test various gel systems which could be used as a material to prevent lost circulation and as a conformance system. The selection criteria were: 1) allowing a good injectivity of the fluid within a reasonable time, 2) a gel strength sufficient to block wormholes, 3) minimal leakoff, and 4) the possibility of acidizing the gel to remove skin effects around the wellbore. A final report describing the screening process for the different gels and the recommended gel system was written to complete this one-year project. **Project Leader:** Bernard Tremblay, tremblay@src.sk.ca.

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

A new 3D physical model was successfully commissioned; its fourth SVX test is underway. The large, high-pressure model can be run at up to 5 MPa and accommodate models up to 875 litres (315 litres fluid volume). Besides testing the equipment and developing operating procedures, initial tests are investigating the dependence of the oil-solvent diffusivity/dispersivity mass transfer coefficients on changes in permeability, particle size, and model scale.

Preliminary results have confirmed that SVX processes involve very complex multi-component and multi-phase fluid flows, while increasing heavy oil recovery 5- to 10-fold over typical primary and waterflood recoveries. The model has already provided some interesting surprises that have improved understanding of the solvent chamber growth and oil production rate. **Project Leader:** Kelvin D. Knorr; knorr@src.sk.ca.



SRC Senior Research Engineer Kelly Knorr at work commissioning a new 3D scaled physical model to be used for testing different vapour extraction solvents and strategies.

Post-Cold Production EOR: Air Injection

Can the wormholes left behind by cold production be used to make air injection work in Lloydminster-type reservoirs? This question is being answered by combining new numerical simulation procedures to predict wormhole development with a new reaction model that will be able to predict combustion front

The Petroleum Technology Research Centre is a partnership of Natural Resources Canada, Saskatchewan Industry and Resources, the University of Regina, and the Saskatchewan Research Council.

stability. The new simulation procedures are currently being developed separately, and are expected to become available for use in this project around February 2006.

A detailed literature survey on hydrocarbon oxidation kinetics was completed; its results, along with experimental data, were used to guide the development of a new reaction model. Not surprisingly, the preliminary version of this model could not accurately capture the complexities of low-temperature oxidation, and further experiments and modelling will be required in the next project year.

Development of an EOR process that uses air injection is an important strategic opportunity for large incremental oil

recoveries in those fields in which the wormhole characteristics are unfavorable towards solvent-vapor EOR processes. Air injection, therefore, represents the second-most promising method for large-scale EOR development in the Lloydminster region. **Project Leader:** Norm Freitag; freitag@src.sk.ca.

Modified Vapex Process for Wormhole Reservoirs

This project is aimed at implementing a "modified Vapex process" for wormhole reservoirs. This study will treat the reservoir as a "black-box"; there is no need to map wormholes to ensure the success of this process. The proposed technique is based on utilizing vertical wells drilled on top of the formation as injection wells, and wormholes as producing pathways. The physical model has been built and tested for conducting flow experiments. A few solvent diffusion coefficient experiments have been completed and the analysis of the results is underway. This project started in September 2005. **Project Leader:** Koorosh Asghari, koorosh.asghari@uregina.ca.

Core Area 2:

Miscible / Immiscible Gas Injection

Improved Heavy Oil Recovery by CO₂ Injection Augmented with Chemicals

This project's aim is to improve the performance of water-alternating-gas (WAG) injection augmented with chemicals by studying the process's mechanisms, leading to better design and/or implementation procedures. Coreflood oil recoveries by surfactant-augmented WAG injection were compared with those of a conventional CO₂ injection scheme at given reservoir conditions. The results indicate that a) the enriched-flue-gas WAG augmented with surfactant produced the most oil; and b) that a low-interfacial-tension surfactant should be placed after a gas slug to better contact a larger area. These unexpected results suggest promising areas for further effort to promote rapid progress to an industry-operated immiscible gas field pilot for western Canada's vast heavy oil reserves. **Project Contact:** Patrick Zhang, zhang@src.sk.ca.

Assessment of CO₂ Miscible Flooding for SE Sask. Light Oil Reservoirs

This project is aimed at expanding the opportunities for light oil production in southeast Saskatchewan through CO₂ miscible flooding. The key to screening candidate reservoirs for CO₂ flooding and a major consideration in optimizing process design is minimum miscibility pressure (MMP). The MMPs of four reservoirs in the region—Weyburn (where a major CO₂ flood is

already a proven success), Alameda, Steelman and Elswick—were compared for their suitability for CO₂ flooding. As well, the MMPs of pure CO₂, and mixtures of CO₂ and light hydrocarbons to lower the MMP were measured for Elswick reservoir. The results will help assess if there is a sound reservoir-engineering basis for using miscible or near-miscible CO₂ flooding in the reservoirs studied. **Project Contact:** Patrick Zhang, zhang@src.sk.ca.

Measurement of Solvent Diffusivity in Heavy Oil & Evaluation of Solvent-Based Recovery Processes

Progress on this project includes three major achievements: 1) The pressure decay method for measuring solvent diffusivity in heavy oil was significantly improved, and the diffusion coefficients of carbon dioxide, methane, and propane in a heavy oil sample under reservoir conditions were measured. 2) A new experimental technique by dynamic pendant drop volume analysis (DPDVA) was developed to measure the solvent diffusivity in heavy oil/bitumen. This method allows both the solvent diffusion coefficient and oil swelling factor of a heavy oil-solvent system to be measured simultaneously at a constant pre-specified high pressure and elevated temperature. 3) The DPDVA method has been successfully applied to measure the diffusion coefficients and oil swelling factors of four pure solvents and three mixture solvents in a heavy oil sample in the pressure range of 0.4-14.0 MPa at 23.9°C. The experimental data were published in *Ind. Eng. Chem. Res.* 44, 4474-4483. **Project Leader:** Peter Gu; peter.gu@uregina.ca.

Core Area 3:

Enhanced Waterflooding

Measuring the Success of Western Canadian Waterfloods

The success of heavy oil waterfloods is highly variable: some obtain up to 700% of primary recovery, while others must be abandoned. This project builds on the 2004 PTRC scoping study of heavy oil waterfloods, and will use mathematics and statistics to increase operators' understanding of the factors behind these differences in success.

The database has been updated with current production data, and expanded to include medium oils. Four new formulae to measure the success of waterflooding have been calculated for each waterflood. We have gathered the reservoir and operating data, including the incorporation of horizontal wells, and have correlated these with the new formulae. Preliminary results indicate that the most important reservoir and operating parameters are very different for heavy oils compared with medium oils. This finding shows that operators cannot manage heavy oil waterfloods by applying the conventional knowledge built up from waterflooding light and medium oils. Western Canadian heavy oil fields need specific research tailored to optimize waterflooding production. **Project Leader:** Gay Renouf, renouf@src.sk.ca.

Visualization of Oil Recovery by Chemical Flooding

This project's aim is to investigate the efficiency of surfactants in releasing/moving oil ganglia from porous media through the development of an innovative laboratory methodology. Various fluid systems, including brine, oil, chemical solution, and oil/brine after equilibration by a surfactant solution, were tested to examine the effect of diverse parameters on the performance of surfactant floods. The results clearly demonstrate the potential of using a visual micromodel to gain a better understanding of the mechanisms of interfacial tension behaviour. A major finding from these tests is the importance of maintaining a lower equilibrated interfacial tension when the injected surfactant solution contacts the remaining oil. However, these results are only preliminary and a further investigation is required using reservoir cores in coreflood tests. **Project Contact:** Patrick Zhang, zhang@src.sk.ca.

Fundamentals of Heavy Oil Waterflooding — A Micromodel Study

This study provides the opportunity to improve the technical and economic aspects of heavy oil waterflooding. It enlarges on a previous SRC/PTRC project (2004) in which a micromodel apparatus was commissioned and initial tests were run to examine the oil–water behavior in a heavy oil waterflood. This year, further qualitative work is being performed on the oil–water interaction as the viscosity of the oil is increased. Emulsification and its relation to water flowrate is being more closely investigated. As well, alkaline/surfactant/polymer (ASP) is being studied in terms of

mechanistic behavior of the water–oil interaction. So far, heavy oil and brine samples have been collected and characterized from several reservoirs; these reservoirs' average permeability has been determined and their pore size estimated; an estimate of linear flow velocity for the waterfloods has been calculated; and tests examining flow rates have begun. **Project Leader:** Cindy Jackson; jackson@src.sk.ca.

Productivity Improvement in the Viking Reservoirs of Southwestern Saskatchewan

The Viking reservoirs in the Kindersley area of southwestern Saskatchewan contain an estimated $300 \times 10^6 \text{ m}^3$ of light oil. However, the oil is in water-sensitive formations and can be prone to precipitating organic scale (wax and/or asphaltene). Thus, oil recovery efficiency is low. Substantial benefit will be gained by finding economic methods to improve the waterflood performance and remove the organic scale or inhibit its formation.

Area maps have been drawn, and well productivities have been examined. Wells with cores have been selected from two areas for plug removal. The plugs have been cleaned and are being characterized and used in corefloods for water-sensitivity studies.

Project Leader: Selim Sayegh; sayegh@src.sk.ca.

Modified Polymers for Water Permeability Reduction

This project is developing a means to overcome excessive water production, improve sweep efficiency, and increase oil recovery. The technique entails modifying natural polymers to better adsorb on reservoir surfaces and plug reservoir pores in water channeling regions.

Flow tests were carried out to study the effect of the modified polymer on the residual resistance factor (RRF) and tertiary oil recovery in double-core tests (two cores in parallel with different permeabilities). The results showed that: 1) The modified polymer could be used to selectively reduce the water mobility in the high permeability core, resulting in a higher RRF there than in the low permeability core; 2) Compared with polyacrylamide, the modified starch could displace more oil from the low permeability core. Under the same differential pressure, the ratio of water mobilities of the two cores was reduced from 34.6 of the initial waterflood to 3.4 of extended waterflood. All the tasks proposed have been completed and the final report is being prepared. **Project Leader:** Mingzhe Dong; mingzhe.dong@uregina.ca.

Development of Biosurfactant-Based Technologies for Enhanced Oil Recovery and Sulfide Reduction

The Weyburn field area in southeast Saskatchewan was chosen as the study site. Site investigation was conducted to facilitate typical soil/groundwater sampling, biosurfactant isolation, and pilot-scale application in the future. Relevant data have been collected and studied, including (1) Weyburn reservoir information (formation pressures, produced fluid volumes, injected fluid volumes, temperature, etc.); (2) Hydraulic and geological properties of subsurface (primary migration pathways, porosity,

permeability, stratigraphy, fracture patterns and associated data, groundwater flow, etc.); (3) Geochemical and biological information (pH, oil characterization, natural medium components, inherent microorganisms species, etc.). Meanwhile, a batch-scale model was designed and will be manufactured for optimizing the experimental

conditions and determining the effect of biosurfactants on enhanced oil recovery. **Project Leader:** Gordon Huang; gordon.huang@uregina.ca.

Core Area 4:

Near Wellbore Conformance Control

EOR by Seismic and Mechanical-Vibration Stimulation of Reservoirs with Multi-Vibro-Energy Sources

A novel recovery method for waterflooded oil reservoirs is being developed which utilizes seismic and mechanical vibration stimulations. Static experiments to obtain the desired relationships among pressure, the geometric dimensions of the oil slug, oil viscosity, and flow volumetric velocity were completed. Dynamic experiments are underway using the developed vibration frame. Numerous tests under various conditions on the mobility of oil in a thin tube have shown—and permitted quantification of—the evident effects of external excitation. Theoretical and numerical analyses of the effects of elastic waves on the mobility of multiphase liquid in porous media have progressed. A quantitative methodology to evaluate the relative displacements between the solid and liquid in a porous medium is developed. Effects of viscosity on the response of the porous medium were quantified with the models established. **Project Leader:** Liming Dai; Liming.Dai@uregina.ca.

Control of Water Coning by Dual Completion

This project addresses the issue of water coning prevention or elimination by dual-completion techniques in hydrocarbon reservoirs with underlying bottomwater. In the project's experimental portion, the model components, different well completions, and various associated equipment were purchased, tested, and assembled. The first step is to study oil viscosity effect at different completion intervals. Baseline tests are nearly complete. Later, we will study the effects of rock and fluid characteristics on water coning by using different dual completion combinations. On the simulation side, a Master's student has been trained and has simulated the physical model. Currently, different combinations of horizontal and vertical wells are being simulated to fine-tune the software model before the

actual water coning scenarios are tackled. Commercially available software provided by CMG is being used for this part of the project. **Project Leader:** Muhammad Ayub; muhhammad.ayub@uregina.ca.

Active Bottomwater Reservoirs

In many reservoirs in Saskatchewan and Alberta, the oil zone overlies an active bottomwater zone; therefore, water channeling is a prevalent concern. This project will improve our knowledge of physics of fluid flow in this reservoir type and develop a method to predict recovery and a means to improve the recovery process through the strategic placement of blocking and mobility control agents, use of production/ injection strategies, and the creation of an artificial gas cap utilizing N_2/CO_2 . This project will also investigate the factors that cause water channeling (viscous fingering), and develop a method for predicting the critical oil production rate. A literature review was concluded, and over 85 simulation runs were conducted. Analysis of the results and history matching is in progress. **Project Leader:** Ezeddin Shirif; ezeddin.shirif@uregina.ca.

Development of Bottomwater Reservoirs in Sandstone and Carbonate Formations Implementing Flow Barrier

Results from a 3D numerical simulation model (using Computer Modelling Group's STARS Simulator) are indicating the promise of practical strategies to apply natural flow barrier(s) for developing a bottomwater reservoir. The cases studied showed that watercut can be postponed and greatly reduced, cumulative oil production increased, and cumulative water production decreased dramatically when barriers exist below the horizontal producer. An experimental setup for studying the possibility of field implementation in conventional and heavy oil reservoirs was designed and the equipment is ordered. A 3D computational model was built to check the designed experimental setup. **Project Leader:** Gary Zhao; gang.zhao@uregina.ca.