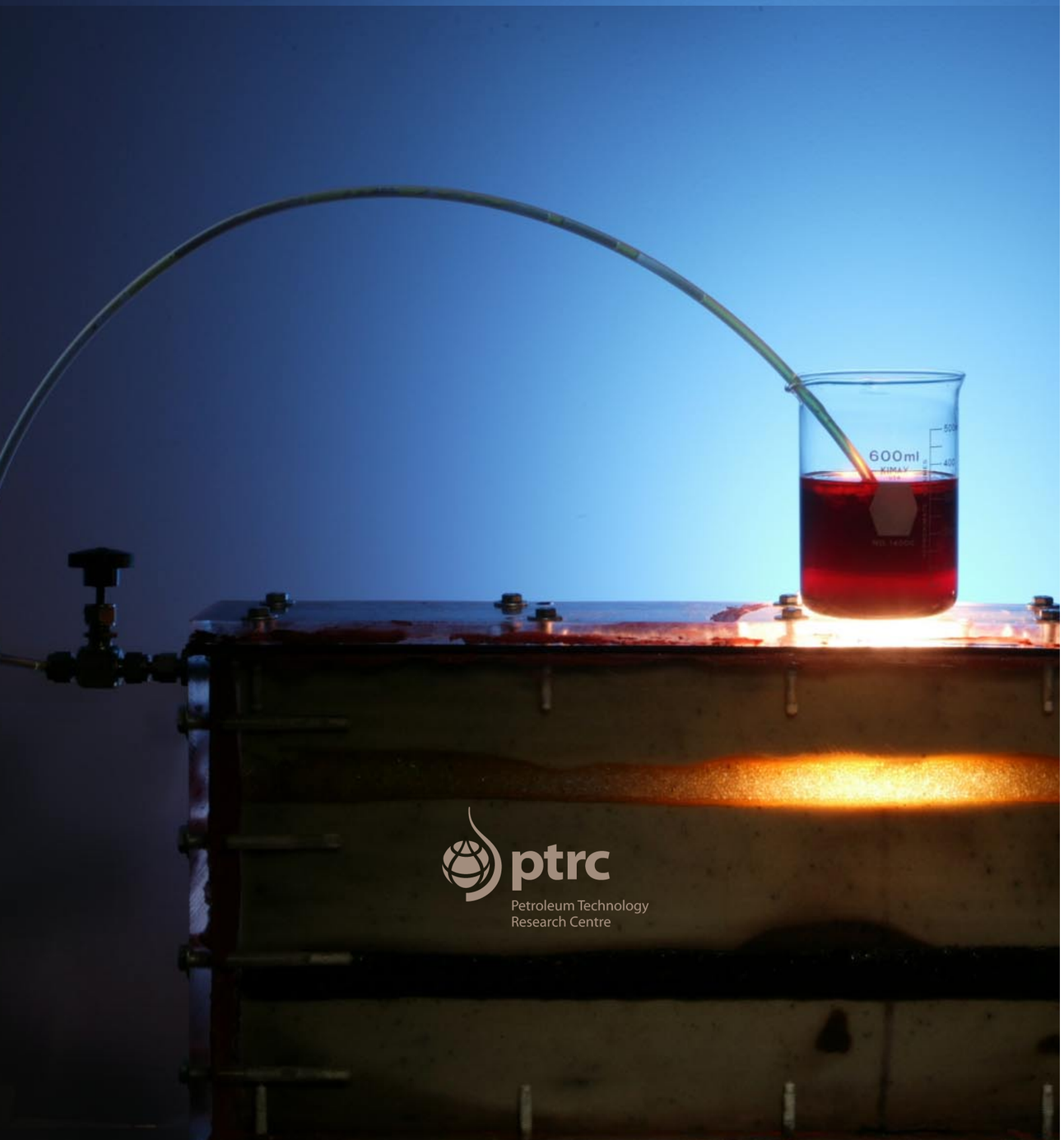
Petroleum Technology Research Centre
2003/2004 Annual Report

# *fuelling excellence in research*



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**About the cover:** Laboratory physical modeling plays a key role in expanding knowledge and developing useful data for industry clients.





# Introduction, mission statement and description of PTRC

PTRC is an internationally recognized innovative leader in the petroleum research and development area that delivers world-class quality basic and applied research for the benefits of the people of Saskatchewan, Canada and our customers.

## PTRC Mission Statement

The PTRC will initiate and support research and development projects aimed at enhancing the production and recovery of Canadian petroleum resources by drawing primarily but not exclusively upon the expertise of the Energy Division of the Saskatchewan Research Council and the Engineering Faculty of the University of Regina.

In addition, the PTRC will ensure that the findings of the work it supports are applied by the petroleum industry. The avenues for this effective application of results will include very close collaboration with the industry participants, presentation of technical papers, and the organization of technical conferences.

## Description of PTRC

The PTRC is a non-profit petroleum research and development corporation located in Regina, Saskatchewan. The PTRC brings a fresh approach to finding, developing and applying innovative technologies and engineering solutions for the petroleum sector.

The PTRC is a collaborative initiative of Natural Resources Canada (NRCan), Saskatchewan Industry and Resources (SIR), the University of Regina and the Saskatchewan Research Council (SRC). The PTRC has financial support from the federal and provincial governments to sponsor research and development projects. An initial five-year term of support has led to renewed funding over four years. The PTRC will attract support for its research projects from the petroleum industry to complement the support it receives from the two levels of government.

# Message from the Chair

This year was truly a watershed year in the young history of the Petroleum Technology Research Centre. In March 2004, our partners in the Governments of Canada and Saskatchewan announced their renewal of financial support over the next four years. This marked the transition from an inaugural phase in which we focused on building sound foundations, to a mature stage in which we will further refine our structure and practices, extend our networks, and give full rein to our potential.

In our first five years, we put a great deal of effort into building effective working relationships: among our primary researchers at the University of Regina and the Saskatchewan Research Council, with our industry partners, and with other private- and public-sector organizations in North America and overseas. We successfully involved these diverse parties in a particularly potent consortium in the Weyburn $CO_2$ Monitoring and Storage project, an exemplar of collaboration. With these relationships well established and bearing fruit, we can now concentrate on effective management.

To attend to this commitment, the Board of Directors has recently become much more engaged in the organization and in helping Michael Monea, our new Executive Director, mold it into a world-class research institute. Audit Finance and Human Resources/ Governance committees have been struck. The former committee has assisted in creating a transparent and flexible multilevel cross-checking system which will satisfy the strict standards necessary for operating a multitasking research organization in today's business environment.

It is gratifying that, even as we strove over the past year to put in place the systems to assure future prosperity, much of our ongoing research was able to achieve a level of success to rival that enjoyed by much larger, longer established programs. The well-run Weyburn $CO_2$ project, mentioned above and described in the essay on Page 5, is now classed as the most successful pilot research project in the world. Now entering its second four-year phase, this project has indeed put the PTRC on the international radar screen. It is our intention to continue to expand our groundbreaking research and make the PTRC, through its collaboration with the United States Department of Energy, truly a world-class centre of excellence in carbon sequestration and enhanced oil recovery.

The PTRC is positioned at a pivotal, exciting time in its evolution. We have achieved recognition for the high caliber of our oil and gas research; our new Executive Director has the necessary skill set and sense of purpose to steer our organization; and our active committee-based board of directors is capable of setting and monitoring the PTRC's strategic direction for years to come.

In closing, I would like to thank Natural Resources Canada, Western Economic Diversification, Saskatchewan Industry and Resources, and our numerous research and industry partners for their continued support.

Frank W. Proto

Frank Proto
Chairman





# Message from the Executive Director

This year, the Petroleum Technology Research Centre made significant progress towards both satisfying shorter-term goals and pursuing longer-term opportunities. In the first case, we've worked to translate laboratory results from our core research program into feasible field applications to support the oil and gas industry in its current activities. In the second case—if these opportunities unfold as anticipated—we may ultimately help to transform the role of the industry in the global economy. How?

Successful sequestration of greenhouse gases in geological formations could make the petroleum industry a major driver of climate change mitigation. The first four-year phase of the PTRC-led Weyburn $CO_2$ Monitoring and Storage Project showed that carbon dioxide flooding in southeast Saskatchewan's Weyburn field was able to improve oil recovery while trapping the injected $CO_2$ .

A major goal of the project's second phase, set to begin in Fall 2004, is to determine the long-term risk of greenhouse gas leakage from the formation. Risk assessment modeling will allow us to confirm the viability of gas injection technology for both industry and regulators, and expand its applicability to a range of geological settings anywhere in the world. We are now negotiating with international collaborators with complementary expertise to develop the PTRC into a hub of excellence in this area.

Vapex (vapour extraction) is another technology with great promise for the industry, thanks to its potential for efficient oil production with substantially reduced environmental impact. The PTRC is collaborating with leading producers, notably Nexen Inc. with whom we have signed a Memorandum of Understanding, on a large effort to demonstrate the process in several heavy oil fields. Advanced Vapex research is typical of our new Field Development Program, whereby the PTRC actively engages in opportunities to take our laboratory results to the field to prove and commercialize them.

To fuel excellence in research, the PTRC provides and takes part in forums for the exchange of knowledge. We hosted the International Energy Agency's 24th Workshop and Symposium on Enhanced Oil Recovery in September 2003 in Regina and attended the North American Energy Summit in New Mexico, among other conferences. Phase 1 of the Weyburn project will be the subject of a session at the 7th International Conference on Greenhouse Gas Control Technologies this September in Vancouver. We are currently negotiating data-access agreements with parties around the world.

The University of Regina, a founding PTRC partner, has built up one of the leading petroleum engineering schools in North America. We are committed to affording U of R graduate students the chance to work on real-world applications under the mentorship of experienced researchers. I would like to thank my own mentor during my first year with the PTRC, Mr. Frank Proto, and the entire Board of Directors for their valuable counsel.

Michael Monea
Executive Director

## Organization Chart


## The PTRC Board of Directors, as of March 31, 2004:

Frank Proto, Chairman, Petroleum Technology Research Centre

Allan Cahoon, VP Research & International, University of Regina

Philip Chan, Senior Manager, Petroleum Engineering, Talisman Energy Inc.

Bryan Cook, Director General, CANMET Energy Technology Centre (Natural Resources Canada)

Carl Henneberg, President, Blacksmith Resources

Mike Langley, VP Business Development, North American Oil Sands Corp.

David Long, General Manager, Heavy Oil & Gas Business, Husky Energy Inc.

Bob Mitchell, retired VP, Talisman Energy Inc.

Brian McConnell, VP Exploration, Tundra Oil & Gas Ltd.

Dan O'Byrne, VP Technical Services, Nexen Inc.

Laurier Schramm, President, Saskatchewan Research Council

Larry Spannier, Deputy Minister, Saskatchewan Industry and Resources

John Zahary, President & CEO, Viking Energy Royalty Trust





Activity in Saskatchewan's oil and natural gas fields is not only proving to be the economic engine of growth for the province, but is fuelling excellence in research as well.

Saskatchewan is the second largest oil producing and the third largest natural gas producing province in Canada.

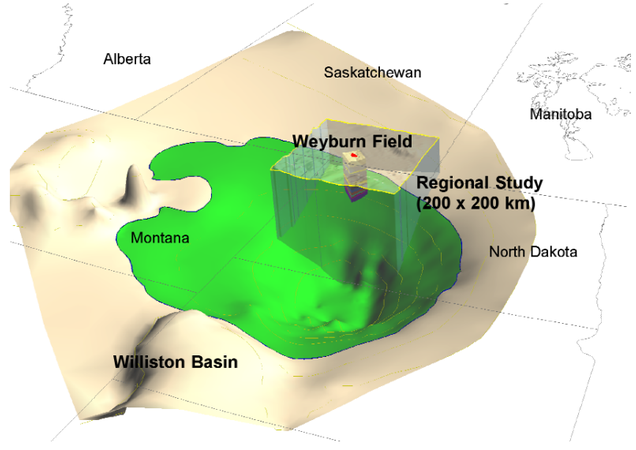
Much of Saskatchewan's rich petroleum resource occurs under conditions that make it difficult to exploit. Even where extraction is more straightforward, conventional recovery methods are nearing their economic limits as reservoirs mature, leaving substantial amounts of oil underground. In heavy oil areas, the remaining prize may be over 90 percent of the initial oil in place. Sustaining and expanding the sector therefore calls forth uncommon ingenuity and far-sightedness from producers and researchers alike.

Researchers at the Petroleum Technology Research Centre (PTRC) work closely with industry to tackle these challenging features—such as very viscous oil, thin pay zones, and heterogeneous reservoir geology. The technologies which they develop, innovate, and apply are more than homegrown solutions to domestic concerns: they are advances with widespread applicability which attract global interest.

## *"Weyburn $CO_2$" the Gold Standard for Field Projects*

A major world-class study underway in southeast Saskatchewan exemplifies how the PTRC is able to build on an opportunity in the oilpatch to fuel excellence in research.

The Weyburn $CO_2$ Monitoring and Storage Project is a unique dovetailing of private-sector and public-sector interests. The PTRC launched the 4-year, $42 million study in 2000 to determine if injecting carbon dioxide into the Weyburn reservoir will economically boost oil recovery while effectively sequestering this important greenhouse gas long-term—beyond 5,000 years—in the geological formation.




**Below:** The Weyburn oilfield (shown in red) lies at the centre of a 200 x 200 km area being studied in the Weyburn $CO_2$ Monitoring and Storage Project. The Williston Basin (shown in tan) is typical of intracratonic sedimentary basins, many of which may contain potential sites for $CO_2$ injection and storage.

The project is endorsed by the International Energy Agency's Greenhouse Gas R&D Programme and is formally recognized by the Carbon Sequestration Leadership Forum, an international climate change initiative. Fifteen industry and government sponsors and 23 research and consulting organizations are involved.

EnCana Corporation is conducting the miscible $CO_2$ flood in the Weyburn reservoir in a $1.1 billion bid to recover an estimated additional 130 million barrels of oil over 25 to 30 years. Before injection began, the PTRC-led research consortium thoroughly described baseline conditions in the Weyburn reservoir, adding critical data to what was already one of the best-documented histories of any field in the world.

**Above:** Weyburn $CO_2$ Monitoring and Storage Project researchers and sponsors tour the facility where the main $CO_2$ pipeline comes into the Weyburn field from Beulah, North Dakota.



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Among the study's 50-plus subtasks, researchers predicted, monitored, and verified the movement of the injected $CO_2$ in the reservoir, using such techniques as four-dimensional seismic surveys and geochemical fluid sampling. Diverse data were entered into numerical simulations to assess the long-term risk of $CO_2$ leaking out of the immediate oil recovery area. The conclusion, arrived at using the most rigourous scientific methodology, is that the risk is extremely small.

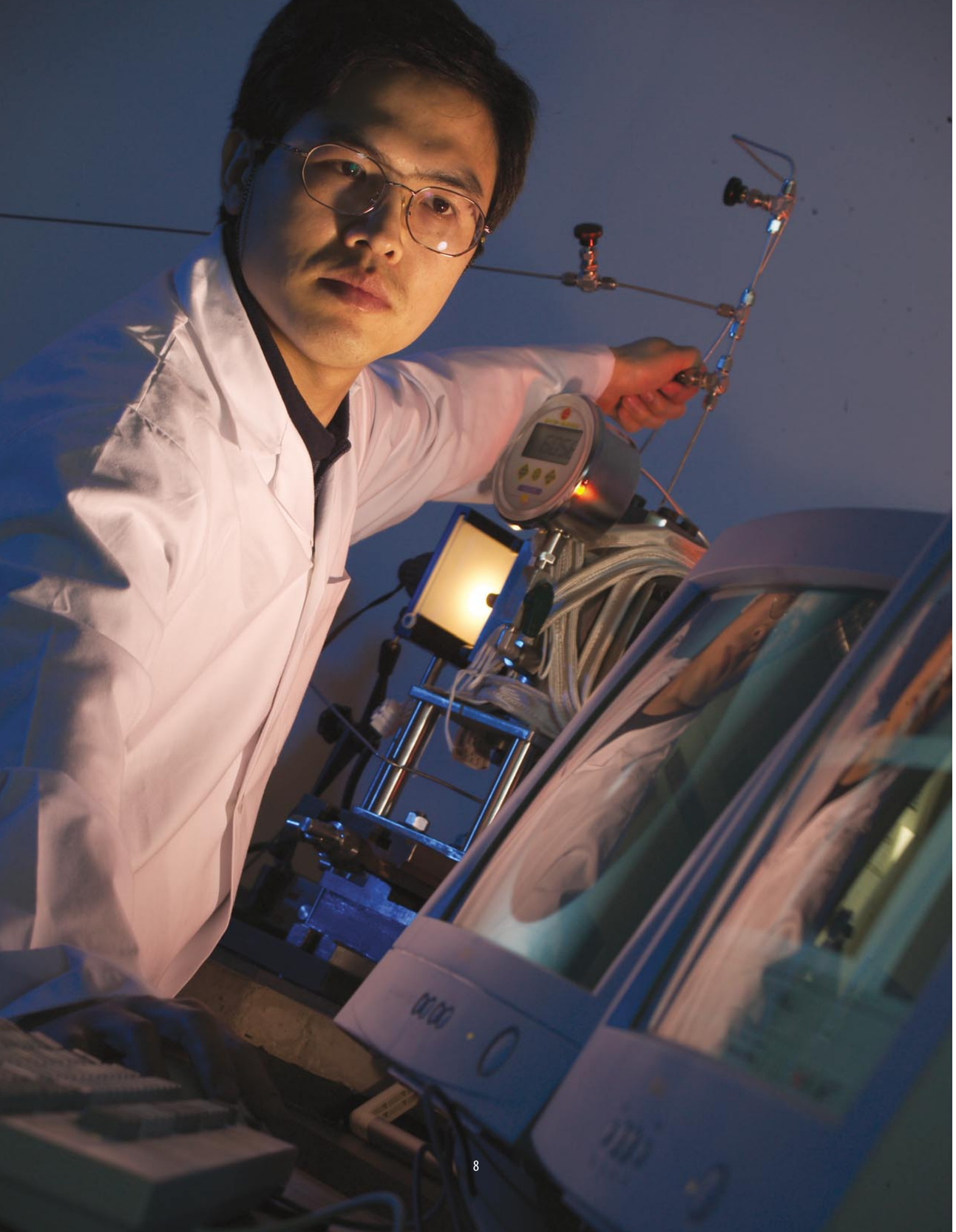
## *New Benchmarks Set for Data Collection, Project Management*

Besides achieving most of its ambitious technical goals, the Weyburn project has laid a solid foundation for future R&D ventures. These include a second phase to field test and refine the results obtained in Phase 1 and in parallel studies such as the $CO_2$ Capture Project led by BP. The extensive Weyburn dataset provides an unrivalled basis for benchmarking risk assessment and reservoir screening tools developed anywhere. Highly effective project management practices evolved over the project's life provide a model that could ensure the success of studies of Weyburn's size, complexity, and global significance in the future.

These assets are now being parlayed into a "hub of excellence" in risk assessment and reservoir evaluation for geological storage of $CO_2$ sequestration and $CO_2$-enhanced oil recovery. The PTRC intends to ignite and connect international expertise and research efforts through the development of state of the art modeling hardware.

The PTRC is forging a further path with its field-focused JIVE (Joint Implementation of Vapour Extraction) program, which aims at proving the Vapex process in several industry-led field pilot tests. This enhanced oil recovery method has the potential to significantly increase production of heavy oil while minimizing environmental impact. Several studies are underway or planned to generate the data needed to deploy the process and to support producers as the pilots progress.

*As the PTRC builds consortia to explore these new areas of opportunity, it also offers its well-established core program in four areas declared by western Canada's oil industry to be of high impact for improving current practices and prospects. These areas—heavy oil (post) cold flow, enhanced waterflooding, near wellbore conformance processes, and miscible/immiscible flooding—are featured in the pages that follow.*



Petroleum Technology Research Centre

## Core Area Number One

# *Heavy oil cold flow, foamy flow and related processes*

Making Saskatchewan's massive heavy oil reserves more productive under cold and foamy flow is a technique being studied by the Petroleum Technology Research Centre.

It's an important area of research for the province and the country because the Saskatchewan heavy oil reserves have been likened to Alberta's oil sands in terms of economic impact and size.

The phenomenon of achieving heavy oil production from vertical wells in unconsolidated sands, without heating, and while allowing sand production, is called cold flow production.

The technique consists of drilling a vertical well, installing a progressive cavity pump and applying high draw down with the pump to achieve production.

In fact, the arrival of reliable progressive cavity pumps in the early to mid 1980s was an important factor for increased heavy oil production from Saskatchewan and Alberta reservoirs.

The term foamy oil flow is used to describe the flow of heavy oil containing a large volume fraction of very small gas bubbles.

A PTRC-commissioned report concludes about six billion stock tank barrels are under cold flow production in Saskatchewan. It also estimates that only about seven percent of this amount is recoverable from these reservoirs.

The goal in this area is to understand cold production processes and their effect on the reservoir (for example, the creation of wormhole networks) and to develop appropriate follow-up enhanced oil recovery technologies.

"Saskatchewan has a huge amount of rich heavy oil reserves. The technology developed in our group is aimed at recovering a significant portion of heavy oil at a cheaper cost and in a more efficient manner."

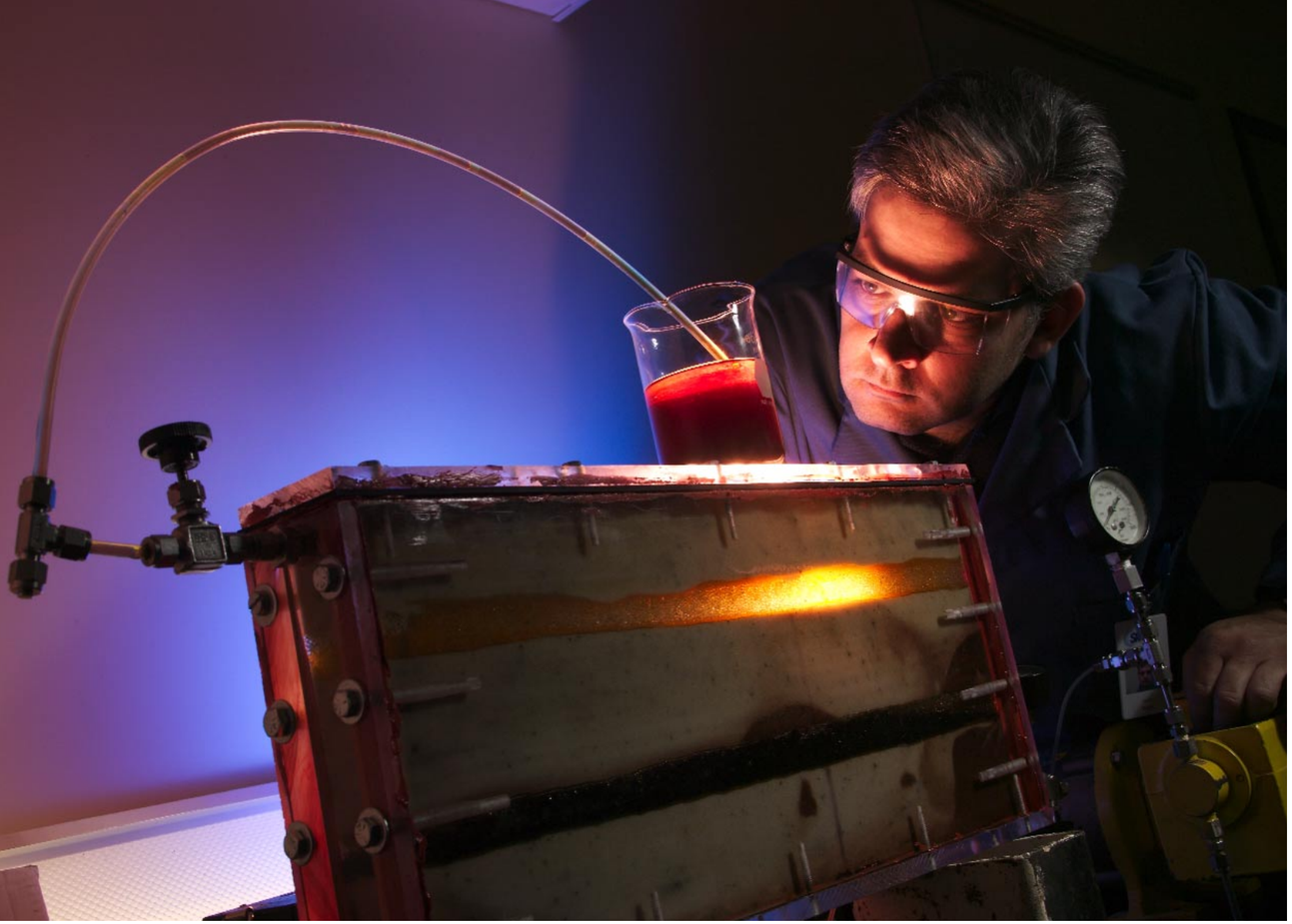
Dr. Peter Gu, University of Regina.

**Left:** Daoyong (Tony) Yang, a Ph.D. student, measures interfacial tension and wettability in oil-brine-$CO_2$-rock systems under different pressures and temperatures. This research will improve understanding of the interfacial interactions among the oil, fluid, and rock for gas flooding and post-cold production.

## *Getting More From Wormholed Reservoirs*

A team at the Petroleum Technology Research Centre is exploring effective technical methods of enhancing oil recovery from wormholed reservoirs by solvent injection.

heavy oil at a cheaper cost



Dr. Peter Gu at the University of Regina is being assisted in the PTRC research project by two graduate students.

A key objective of the two-year research project is to develop an experimental method of measuring the diffusivity of solvent in heavy oil, which is an important parameter in post-cold heavy oil production (CHOP) under reservoir conditions.

Research engineers are confident that this project will identify the optimal technical methods and conditions for solvent injection in wormholed reservoirs, and reduce associated capital and operating costs, perhaps saving the oil industry millions of dollars.

**Above:** Technologist Kevin Rispler monitors fluid production from a physical model simulating a "wormholed" reservoir. The use of gel-foam systems has the potential to block excessive water production in such reservoirs and prevent well abandonment.

The PTRC project will also study the effects of solvent and oil type, temperature and pressure on diffusion efficiency within the wormholed pockets of an oil reservoir.

Results from the lab tests will be used to recommend applications in oil fields.



Petroleum Technology Research Centre

## Heavy Oil Cold Flow, Foamy Flow and Related Processes

*PTRC Researcher Profile*

# *Peter Gu*

Peter Gu thinks the PTRC is an excellent vehicle for exercising his twin passions: applied research and teaching. The associate professor in the University of Regina's Petroleum Systems Engineering program appreciates the potential for his high-tech academic research to be meaningfully applied.

"Direct application of our lab research findings in oil fields can generate substantial economic, environmental and social benefits," says Dr. Gu.

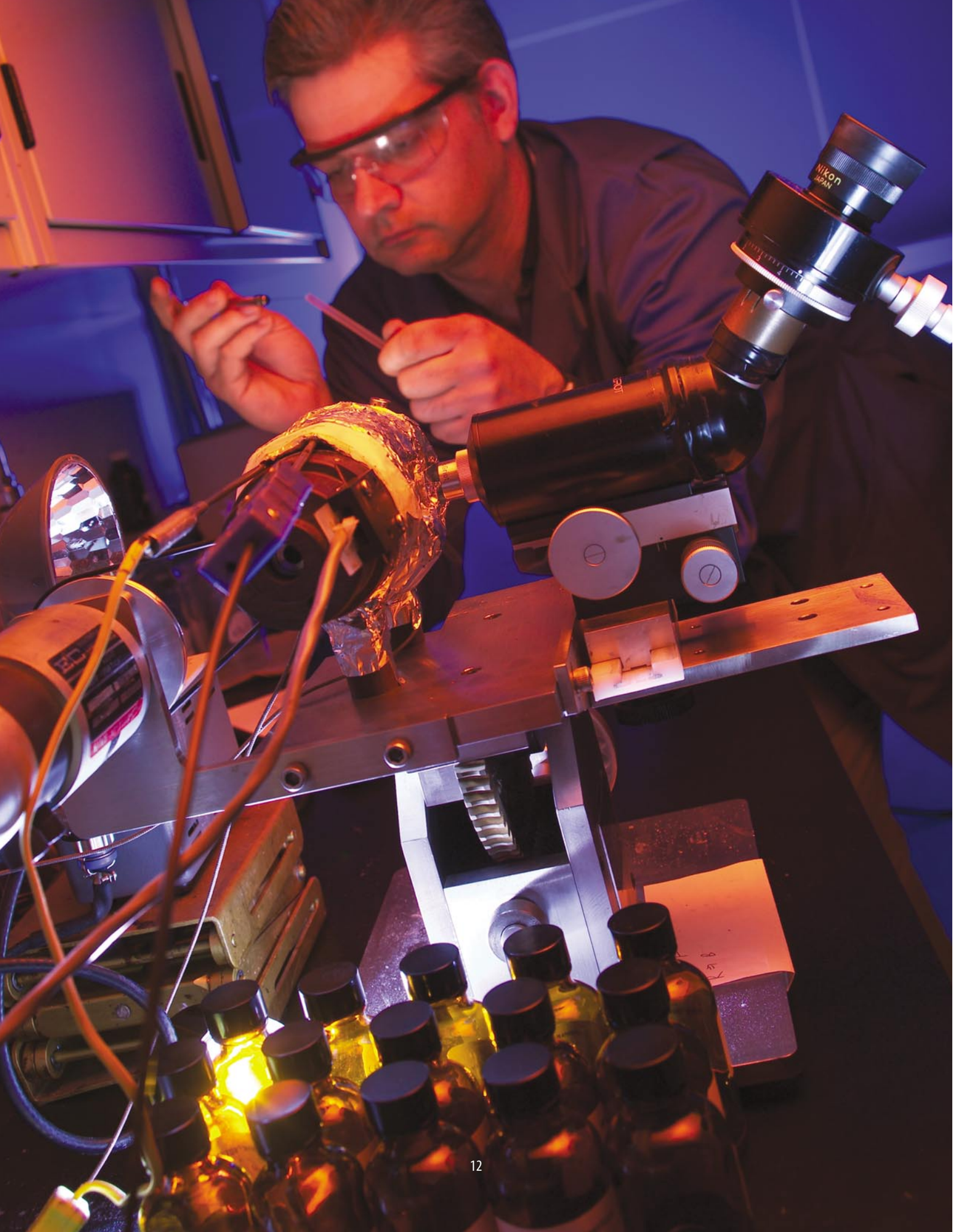
At the same time, he has the opportunity to inspire a new generation of students with his enthusiasm and high standards for conducting research and communicating results.

Dr. Gu earned his Ph.D in mechanical engineering from the University of Alberta in 1999. His B.Sc and M.Sc degrees were granted by the Nanjing University of Science and Technology, China.

He is leading the PTRC project investigating the use of solvents in wormholed reservoirs. He is also studying other aspects and methods of enhanced oil recovery.

Dr. Gu also maintains a significant professional profile. He is the author or co-author of over 30 refereed journal papers and 20 conference papers and is an active member of several professional associations.

*"Direct application of our lab research findings in oil fields can generate substantial economic, environmental and social benefits"*






# *Enhanced waterflooding*

There are more than 200 active, yet mostly mature, waterflood projects in Saskatchewan.

An important aspect of the work being done through the Petroleum Technology Research Centre is to develop new techniques to improve the oil recovery in those waterfloods.

Many waterflood projects in Saskatchewan are still economical even after reaching very high water production levels in the range of 90 percent and more.

Waterflooding is the most common of oil recovery methods in the province. It is a proven technology that is reliable, low-risk and often economically successful even at low recovery levels. Water used for flooding is not the quality of drinking water.

Waterflooding started as an oil patch production technique by accident.

Water escaped from abandoned wells into producing wells in a Pennsylvania field in 1880. The operators realized that the subsequent oil recovery was significantly larger than their primary production. The number of waterflood operations expanded rapidly during the 1920s to 1960s in the United States and around the world.

Saskatchewan too has many active waterflood projects, which are playing a significant role in improving oil recovery.

The PTRC's enhanced waterflood area team works on projects that may improve the province's economy significantly in a shorter period of time.

To accomplish this, PTRC will initiate joint ventures with well-respected research organizations and universities.

**Left:** Technologist Kevin Rispler uses the spinning drop tensiometer to screen chemicals for the optimal ASP (alkaline-surfactant-polymer) combination which will obtain minimum interfacial tension and boost oil recovery.

## *Adding Gas To Water Helps Oil Flow*

Making water flow up, rather than down, in an oil reservoir is the goal of one project underway at Petroleum Technology Research Centre.

Operators of waterfloods continue to look for methods of increasing oil production. One approach is to modify the water.

Water is less viscous than oil so, when it travels from an injection well to a production well, it takes the path of least resistance. That's usually a path swept by water previously injected.

Because the water is heavier than the oil, that swept area is likely to be the lower levels of the reservoir.

Making water flow up, rather than down, in an oil reservoir is the goal of one project

Making water flow up rather than down

**Above:** The PTRC invested in upgrading SRC's portable field laboratory, which provides immediate on-site analysis during field pilot projects.

PTRC researchers want to find a way to encourage the water to travel upwards into previously untouched upper reaches of the oil reservoir.

To do that, the water needs to have its density lowered and its viscosity raised at the same time.

Adding colloidal gas aphrons (CGAs) and viscosity-thickening agents to the water can produce those characteristics.

Colloidal gas aphrons are the extremely small bubbles in a suspension or microfoam. Their name derives from the Greek word for foam, aphros.

For more than thirty years, researchers in the United States have been making aphron solutions, but not until the mid 1980's did any real-world applications emerge.

Most of these applications focus on biotechnical and medical areas such as protein recovery or ultrasound imaging.

Aphrons, in recent years, have been incorporated into the petroleum industry with their addition to drilling muds.

The initial work was done in 1997 by researchers at the Alberta Research Council (ARC). Those same ARC researchers are partnering with the Saskatchewan Research Council (SRC) to further the aphron research in waterflooding for the PTRC.

The research team has tested a number of surfactant/viscosity agent combinations to produce long-lasting stable CGA solutions. The best of these will be characterized at high pressure, and examined in a physical waterflood simulation.





*PTRC Researcher Profile*

# *Cindy Jackson*

Cindy Jackson likes to go boldly where no man or woman has gone. "It's neat doing work that you know may make you "the first" to go there—pushing on the limits of what is unknown. We are explorers."

"Our work will ensure that the right technology will be available for the future when the present technologies being used "hit the wall"—and this will happen. Our team has to look into the future and see what will come, anticipate and then develop the technologies that will be needed. It means the resource in this province will continue to be developed: providing jobs, needed energy and provincial revenues."

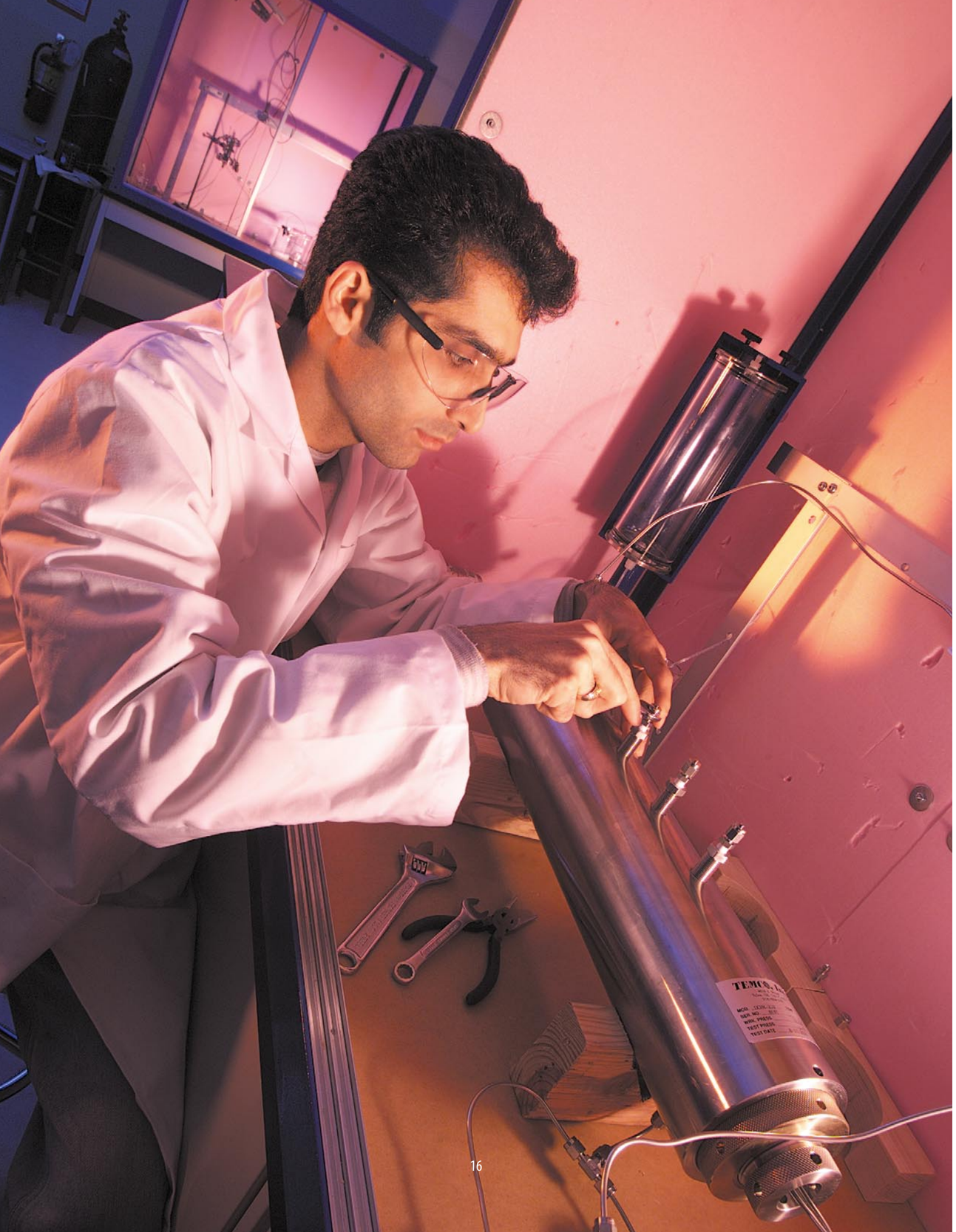
Jackson is a Research Scientist within the Energy Division of the Saskatchewan Research Council. She has developed diversified practical research experience from her almost 19 years at SRC.

Jackson is part of the team conducting research on low cost chemicals for a number of industrial clients along with the Petroleum Technology Research Centre.

Other areas of her expertise include microwave processing for upgrading of heavy oil, field upgrading of heavy oil, and biofilm treatment of polluted waters.

Jackson brings this same attitude of pushing the boundaries to her involvement in the Canadian speedskating scene. She has organized competitions at the provincial, national and international levels, and is president of the Saskatchewan Speed Skating Association.

*"It means the resource in this province will continue to be developed: providing jobs, needed energy and provincial revenues."*






Petroleum Technology Research Centre
Core Area Number Three

# *Near wellbore conformance processes*

About 10,000 Saskatchewan oil wells that have been suspended or are nearing abandonment may get a second chance on life and continue to produce, as a result of work to be conducted by the PTRC on developing methods for near wellbore conformance control.

Conformance control is any action taken to improve the injection or production profile of a well. It includes procedures that enhance recovery efficiency, improve wellbore casing integrity and satisfy environmental regulations.

Most of Saskatchewan's oil and gas is produced from mature fields in the Western Canadian Sedimentary Basin.

In many cases, oil wells are facing conformance problems caused by excessive water production or wax and asphaltene precipitation.

Many factors are responsible for near wellbore conformance problems in wells and so many treatments have been devised to solve those problems.

If just five percent of these reserves could be recovered due to research in this area chosen by the PTRC, this could generate a huge economic impact for the province and the country in the $3 billion (US) range.

**Left:** Loran Taabbodi assembles a high-pressure core holder as part of the flow experiments for investigating the application of gels for water and carbon dioxide conformance control.

## *Application of Gels for $CO_2$ Conformance Control*

Finding a more effective way to use carbon dioxide to displace crude oil is the goal of a project underway at the Petroleum Technology Research Centre.

Dense carbon dioxide is an ideal displacement fluid for many crude oils, but fractures in the reservoir sometimes make it difficult to achieve desirable flow patterns.

A possible solution being developed is to inject gelling solutions to block the existing pathway of the carbon dioxide flow and, as a result, force the carbon dioxide through the low-permeability and unswept regions of the oil reservoir.

The theory is simple; the concern is complex.

In-depth gel placement has been used for water shut-off purposes quite extensively. But there are very few studies on the application of this process for carbon dioxide conformance control, particularly in carbonate reservoirs, such as the Weyburn oil field.

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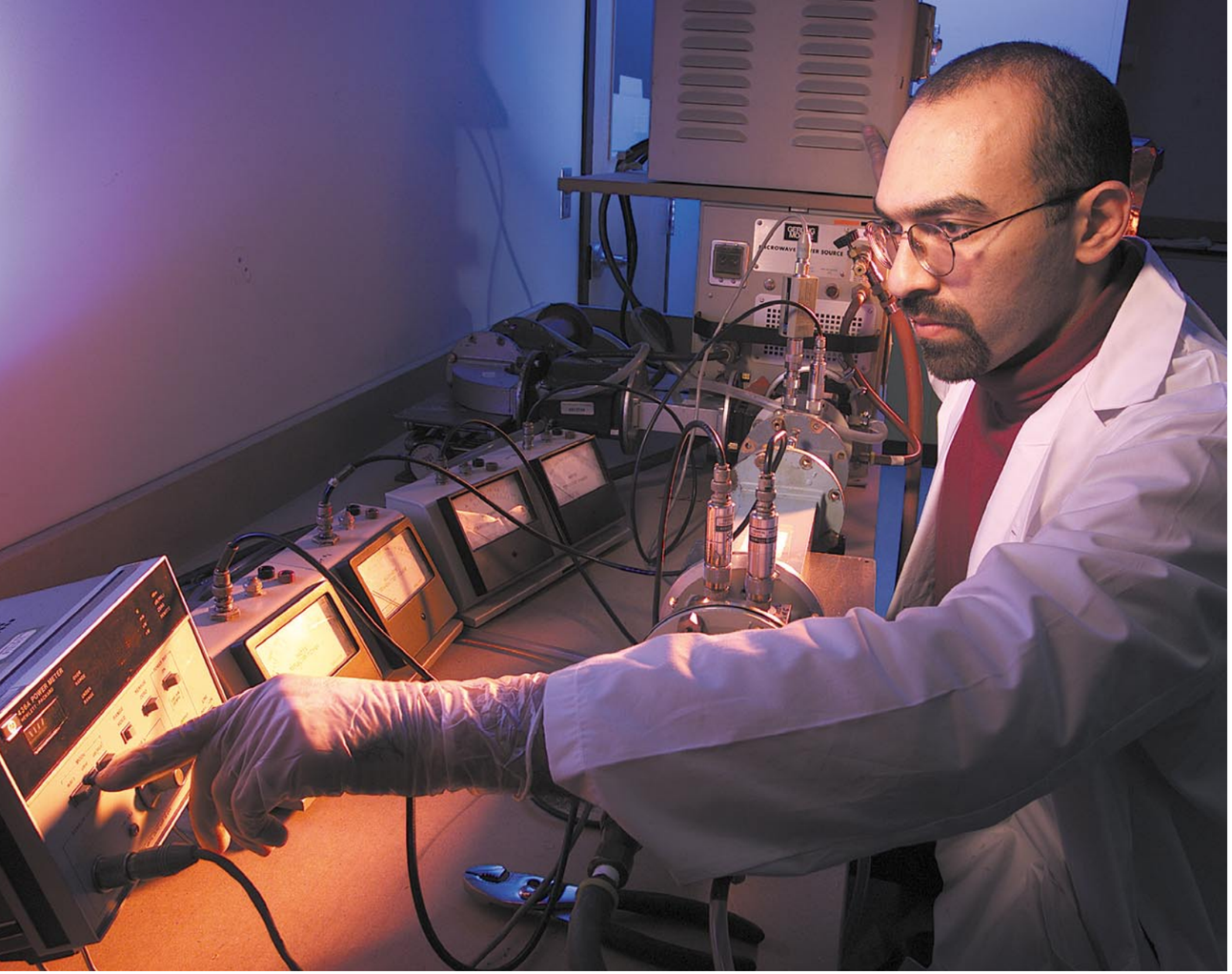
this could generate a huge economic impact



The PTRC research project goal is to fill the existing gap in the research of in-depth gel placement for application of gel systems for carbon dioxide flooding processes in carbonate reservoirs with emphasis on the Weyburn oil field.

Developing techniques for carbon dioxide conformance control for Saskatchewan oil reservoirs will lead to an incremental increase in the oil production and reduce the amount of gas needed to be injected to produce a given amount of oil.

**Above:** Mohammad Sheidaei, a graduate student at the University of Regina, studies the application of electromagnetic heating as a means to prevent wax deposition.

Considering the huge amount of oil reserves in fields such as Weyburn, any incremental increase in oil production translates into a considerable benefit for the Saskatchewan economy.



Petroleum Technology Research Centre

## Near Wellbore Conformance Processes

# *PTRC Researcher Profile*
# *Koorosh Asghari*

While he was earning his Ph.D in chemical and petroleum engineering at the University of Kansas, Koorosh Asghari became a lifelong fan of the university's Jayhawks basketball team. He also became convinced of the value of permeability modification as a way to increase the sustainability of limited oil resources.

The concept of reducing permeabilities of selected regions of a reservoir to improve the sweep efficiency of a flooding process is well accepted in the United States, but less so in Canada. Dr. Asghari, now an associate professor of Petroleum Systems Engineering in the University of Regina's Faculty of Engineering, is enthusiastic about selling Canada's oil producers on the method.

Asghari has extensive experience with conducting experiments with carbon dioxide and application of gels for blocking the flow of carbon dioxide at reservoir conditions.

He is the principal investigator for the Petroleum Technology Research Centre project into the application of gels for carbon dioxide conformance control in the Weyburn oil field.

He serves on a variety of university and professional committees, notably as chair-elect of the south Saskatchewan section of the Canadian Institute of Mining and Metallurgy (CIM).

Asghari earned both his M.Sc and B.Sc degrees in his native Iran. Now he is motivating students in Canada with his love of engineering. He also insists that they too cheer for the Jayhawks.

*"Being a research scientist gives me the opportunity to apply my educational background to problems and issues facing our industries, economy and people of Saskatchewan. By developing new and/or more efficient ways of resolving these problems, I will be helping the sustainability of my community."*




# *Miscible/ immiscible flooding*

New combinations of gases and solutions are being pumped into the ground to help extend the life of Saskatchewan's oil reserves.

Injecting carbon dioxide or hydrocarbon solvent into the oil reservoirs may be the key to unlocking production of light, medium and heavy oil remaining after fields have reached their economic limit through conventional drilling and waterflood methods.

The objective is to develop a method to extract hundreds of millions of barrels still in the ground.

Both carbon dioxide and hydrocarbon solvent techniques are relatively new in Saskatchewan but are yielding positive results.

Carbon dioxide flooding is a proven oil field technology that has been successfully applied for more than 20 years in West Texas and New Mexico, where the gas is readily available and inexpensive.

As a result, carbon dioxide injection has become the leading enhanced oil recovery process in the United States, adding decades of life to reservoirs believed depleted and millions of barrels of oil to the world supply.

Canada is different.

The emphasis in Canada is more on hydrocarbon injection, with 29 miscible hydrocarbon projects and two miscible carbon dioxide projects being implemented.

**Left:** Technologist Susan Fletcher analyzes gas composition to support monitoring of a client's field trial.

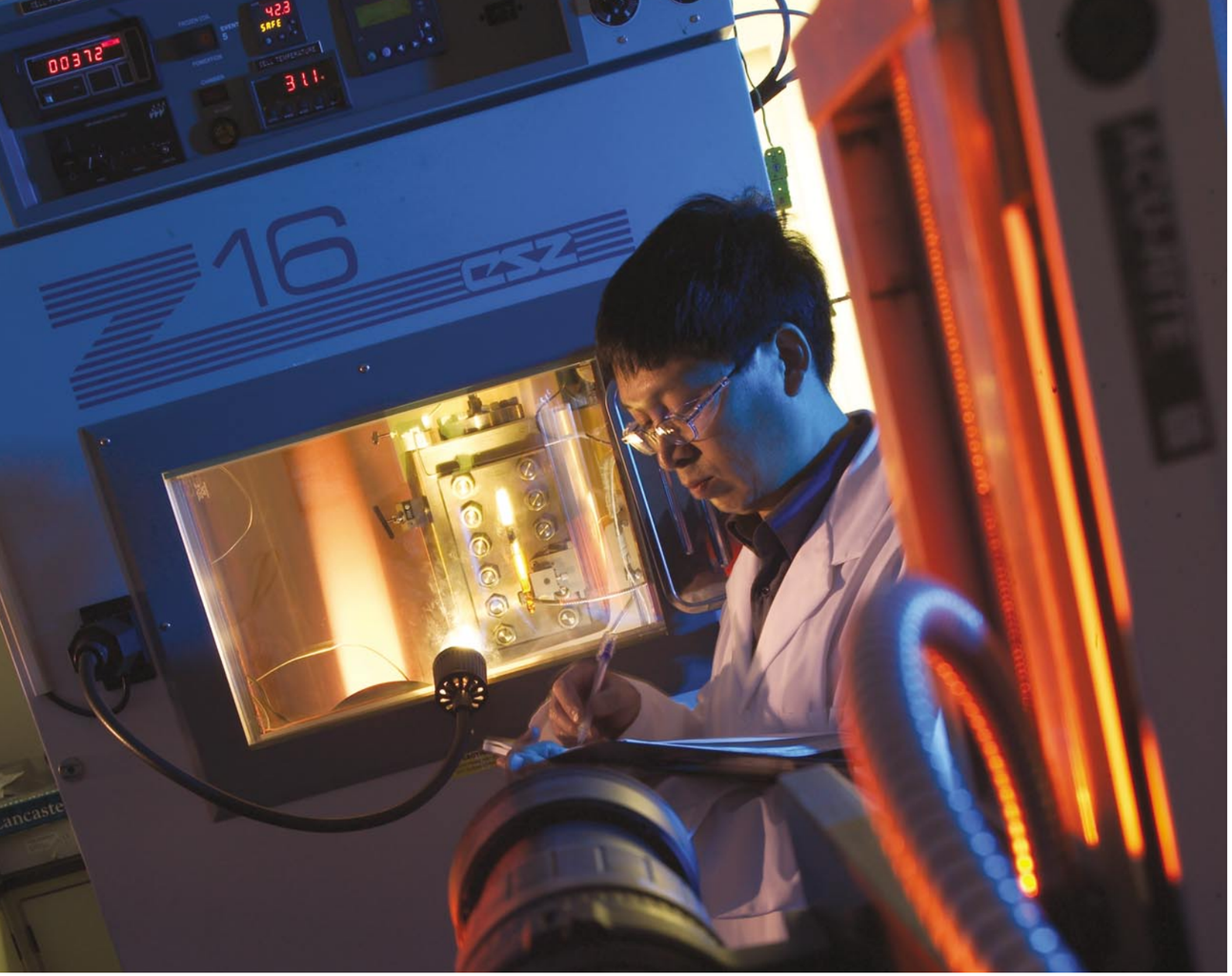
## *Enhanced Oil Recovery by Flue-Gas/$CO_2$ Huff-n-Puff in Saskatchewan Reservoirs*

Huff-n-puff, one of the more colourful terms used in the oilpatch, is an enhanced oil recovery method being developed and optimized by PTRC researchers for Saskatchewan applications. The huff phase involves injection, through a single well, of a gas solvent such as carbon dioxide or flue gas, which "soaks" in the reservoir for one to two weeks. This gas reduces the viscosity and swells the volume of the oil. Water can also be added to pressurize the reservoir. The mobilized oil is produced through the same well (puff phase) and this cycle is repeated.

*Quick improvement in oil production adds up to a rapid payback on investment*

Huff-n-puff technology offers several advantages that make it attractive to oil producers. It uses existing—usually underperforming—wells, so capital costs are low, and it can be applied to as few or as many wells as needed. Quick improvement in oil production adds up to a rapid payback on investment. The injection of a greenhouse gas rather than steam, and the potential to

rapid payback on investment



**Above:** Shuliang Li records test data in a phase behaviour experiment to evaluate $CO_2$ solubility in oil, an important parameter in the design of carbon dioxide flooding projects.

trap some of that gas in the reservoir, makes the process more environmentally friendly.

This year, a team led by Patrick Zhang of Saskatchewan Research Council tested the technology for a moderately light oil from southeast Saskatchewan. The project was supported by the PTRC and four major oil producing companies. Results from laboratory phase behaviour and coreflood experiments suggested that, while the process worked well, it would perform even better with medium oil. That's because the more viscous the oil, the higher the post-waterflood oil saturation in the reservoir is likely to be. These results are significant for Saskatchewan, which has large underexploited deposits of medium oils requiring innovative approaches to recovery in order to sustain production.

Zhang's team is proposing a new twist as they embark on a new phase to apply huff-n-puff to medium oils—the addition of a foaming agent to the gas stream. This is expected to prolong the contact time between gas and oil and help to detach the oil from the reservoir rock.



Petroleum Technology Research Centre
Miscible/Immiscible Flooding

*PTRC Researcher Profile*

# *Sam Huang*

Sam Huang is satisfied to have contributed significantly to a world-class project while raising his family in Saskatchewan's friendly small-town atmosphere. The Manager of the Enhanced Recovery Technologies section of the Energy Division at the Saskatchewan Research Council has been advancing $CO_2$ injection for light oil recovery since 1986. His team produced important data for the design and implementation of the Weyburn $CO_2$ enhanced oil recovery project.

The Taiwan-born Huang joined the SRC in 1986 from Gulf Canada Limited where he had worked for five years as a research scientist in Mississauga, Ontario. He also did research with the Department of Chemical Engineering, University of Alberta.

In 1975, Huang earned his Ph. D. in Physical Chemistry from Marquette University, Milwaukee. He obtained the equivalent of a Bachelor of Science in chemical engineering from the Taipei Institute of Technology in Taiwan in 1968.

Huang is a prolific author with 40 refereed technical papers in scientific journals and 40 conference papers to his credit. In addition, he has published 82 technical and research reports.

*"My research work at the PTRC can help provide a cleaner (and more friendly) environment for the residents of Saskatchewan, by reducing emissions of greenhouse gases, and at the same time help create wealth (i.e. financial benefits with higher revenues) for the province through the enhanced oil recovery/production."*

# PTRC Research Projects

*The following project descriptions are snapshots, as of March 31, 2004, of the work being carried out in the PTRC's core research program. Project proposals and summary sheets describing the proposed R&D program for 04/05 are available from the PTRC.*

## Heavy Oil Cold Flow

### Phase Behaviour Data for Vapex Correlations

***Aims:*** To enable oil producers to operate Vapex field projects at optimum fluid property conditions; to establish the range of conditions, governed by phase behaviour issues, for successful Vapex implementation. ***Highlights:*** New equipment was commissioned, a literature survey completed, and methods for correlating/predicting asphaltenes precipitation were assessed. ***Status:*** Continuing. ***Project leader:*** Norman Freitag, SRC.

### Propane / Heavy Oil Diffusion Measurement

***Aim:*** To improve the performance prediction and design of Vapex projects through development of a technique to accurately measure molecular diffusion coefficients of Vapex solvents into heavy oil. ***Highlights:*** Work on optical system delayed by unexpected costs; U of R team wrote a program based on the diffusion equation which can support processing of measured diffusion data. ***Status:*** Further work will be proposed under PTRC's Field Development Program. ***Project leader:*** Bernard Tremblay, SRC.

### Generic Modeling of Wormholed Reservoirs

***Aim:*** To improve sweep efficiency of post-cold flow processes in wormholed reservoirs. ***Highlights:*** A baseline test obtained up to 18% additional recovery of initial oil in place when hot water was injected in open-wormholed sandpack. Numerical calculations done to extrapolate results to the field. ***Status:*** Final report nearly complete. ***Project leader:*** Bernard Tremblay, SRC.

### Solvent-Based Post-CHOP in Wormholed Reservoirs

***Aim:*** To improve recovery from wormholed reservoirs while reducing capital and operating costs of solvent injection. ***Highlights:*** Oil-$CO_2$ and brine-$CO_2$ two-phase tests are completed. At present, oil-brine-$CO_2$ three-phase tests are being undertaken at elevated pressure and temperature. ***Status:*** Nearly complete. ***Project leader:*** Peter Gu, U of R.

## Enhanced Waterflooding

### Heavy Oil Waterflooding Scoping Study

***Aim:*** To develop a database of heavy oil waterfloods and, by identifying common factors of success or failure, develop screening criteria for future floods. ***Highlights:*** Statistical analysis of heavy oil waterfloods in Saskatchewan and Alberta was integrated with interviews of engineering and field personnel. Five reservoir parameters found to be useful as screening criteria. Effect studied of operating strategies (e.g., injection throughput, use of horizontal wells, selection of injection wells) on waterflood success. ***Status:*** Final reporting complete; workshop with industry participants planned. ***Project leader:*** Doug Soveran, SRC.

### Low-Cost Chemicals for Enhanced Waterflooding

***Aim:*** To reduce the costs of chemically enhanced waterfloods by identifying, and testing effectiveness of, low-cost sources of caustic or substitute (cleaned pulp smelt). ***Highlights:*** A lamella clarifier unit, alone and with a flocculent, successfully removed suspended solids. Oxidation tests as well as a waste exchange and pulp mill survey are continuing. ***Status:*** Ongoing. ***Project leader:*** Cindy Jackson, SRC.

### ASP Flooding in SW Sask. Medium Oil Reservoirs

***Aim:*** To enable field test of a cost-effective alkaline/ surfactant/ polymer flooding technique. ***Highlights:*** Promising results obtained in reservoir rock corefloods; lab work suggested that in-situ formation of an oil bank is critical to success, even when low interfacial tension between the oil and ASP solution is attained. ***Status:*** Complete; new phase proposed to focus on oil coalescence and movement mechanisms. ***Project leader:*** Sam Huang, SRC.

### Enhanced Waterflooding Using Colloidal Gas Aphron (CGA) Solutions

***Aim:*** To examine the use of microbubble solutions to lower the density and raise the viscosity of injected water to sweep previously unaccessed portions of a reservoir. ***Highlights:*** Wide variety of surfactants screened; one shown to create relatively long-lived bubbles will be tested in a two-dimensional scaled physical model, and then further, at Alberta Research Council, under high pressure and in a coreflood. ***Status:*** Ongoing. ***Project leader:*** Doug Soveran, SRC.

### Modified Polymers for Water Permeability Reduction

***Aim:*** To develop a means to overcome excessive water production, improve sweep efficiency, and increase oil recovery. ***Highlights:*** Our partner at the University of New Brunswick modified polymers and, in tests, showed that cationic starches with relatively high molecular weight and high charge density tend to adsorb strongly on core samples. ***Status:*** Ongoing; flow tests underway at University of Regina to determine resulting residual resistance factors using the modified polymers. ***Project leader:*** Mingzhe Dong, U of R.





# PTRC Research Projects
*continued*

## Near Wellbore Conformance Control

### Information System for Saskatchewan Reservoirs for Applying Conformance Control Techniques

***Aim:*** To develop an easy-to-use information system enabling reservoir engineers and managers to select suitable conformance control techniques for any given reservoir. ***Highlights:*** A database, combined with a knowledge-based expert system approach, was structured, data-populated, and improved in response to industry input. ***Status:*** Nearing completion. ***Project leader:*** Koorosh Asghari, U of R.

### Developing Near Wellbore Conformance Technologies for Wormholed Reservoirs

***Aim:*** To develop new and modified gel-foam systems for effectively blocking wormholes in Lloydminster-type reservoirs and increasing ultimate oil recovery from these fields. ***Highlights:*** A range of surfactants and foam-stabilizing materials were screened, and their resistance tested in glass bead tubes and hollow tubes (one-quarter-in. dia.) mimicking wormholes. ***Status:*** Ongoing. ***Project leader***: Koorosh Asghari, U of R.

## Miscible/Immiscible Gas Injection

### Enhanced Oil Recovery by Flue Gas / $CO_2$ Huff-n-Puff in Saskatchewan Reservoirs

***Aim:*** To determine if flue gas/$CO_2$ huff-n-puff will work cost-effectively in waterflooded oil reservoirs. ***Highlights:*** Significant recovery of a relatively light oil was obtained in sandpack corefloods. Because a key criterion was higher waterflood-residual oil saturation, the process is expected to be more applicable to medium oil reservoirs. ***Status:*** Complete; new phase incorporating surfactant addition proposed for medium oils. ***Project leader***: Sam Huang, SRC.

### Immiscible $CO_2$ / Enriched Flue Gas Injection for Heavy Oil Recovery

***Aim:*** To develop a viable, cost-effective EOR method for thin heavy oil reservoirs and accelerate its application. ***Highlights:*** PVT analysis of oil–gas solvent systems and water-alternating-gas corefloods using reservoir sands were carried out. ***Status:*** Final report written. Good—but less-than-expected—oil recovery results prompted proposal of a second phase to look at special requirements of pressure-depleted reservoirs and other aspects of heavy oil gas injection. ***Project leader***: Sam Huang, SRC.

### Effects of Capillary Pressures, Interfacial Tension and Viscosity in Vapex

***Aim:*** To improve predictive models and reservoir screening criteria for Vapex field application; focus on the roles played by capillary pressure and interfacial tension in propagating the vapor/gas chamber formed in the reservoir. ***Highlights:*** A thorough literature search was completed; new physical models designed and commissioned; and several primary, secondary and advanced levels of experimental studies completed. ***Status:*** Ongoing. ***Project leader***: Muhammad Ayub, U of R.

## Other Areas

*The PTRC also funded projects outside the four core R&D areas; selected studies are described below.*

### Displacement of Heavy Oil Via Interfacial Instability

***Aim:*** To develop a viable chemical solution injection process for thin heavy oil reservoirs, in which low interfacial tension, mass transfer, and mechanical shear combine to cause the oil to self-disperse into and flow through the water phase. ***Highlights:*** Phase I was completed and Phase II begun using field samples from two oil companies. Studies included emulsification, chemical loss, and coreflood tests. ***Status:*** Ongoing; this project will now be offered under PTRC's Field Development Program. ***Project leader***: Mingzhe Dong, U of R.

### Application of Gels for $CO_2$ Conformance

***Aim:*** To examine optimal gel composition and gel placement techniques for conformance control (improved sweep efficiency) of carbon dioxide in Weyburn field. ***Highlights:*** Gel systems were designed and formulated to effectively block the flow of carbon dioxide and water in porous media. ***Status:*** Completed; field tests will be proposed to industry. ***Project leader***: Koorosh Asghari, U of R.

### Biosurfactant-Enhanced Technologies for Remediation of Petroleum-Contaminated Sites

***Aim:*** To evaluate ability of newly developed biosurfactants to remove subsurface hydrocarbon contamination. ***Highlights:*** Biosurfactants were isolated from two strains of soil and produced in bulk. Their performance in enhancing bioremediation, and their toxicity and biodegradability, were quantified in a pilot-scale model. ***Status:*** Nearing completion. ***Project leader***: Gordon Huang, U of R.

### Interfacial Phenomena in $CO_2$ Flooding

***Aim:*** To improve understanding of how $CO_2$ miscible flooding enhances oil recovery and sequesters $CO_2$. ***Highlights:*** High pressure tests were carried out at reservoir temperature to determine the effects of $CO_2$ flooding on the oil/rock/brine reservoir system. ***Status:*** Completed. ***Project leader:*** Peter Gu, U of R.

**Separation of Oil / Water Emulsions Using a Coalescer Column**
***Aim:*** To develop an effective mechanical phase separation technique for petroleum industry applications. ***Highlights:*** Single- and two-phase flow tests were carried out; parametric studies focused on effect of flow rate, inlet oil concentration, column length, and packing size; conditions for optimal performance were identified. ***Status***: Completed. ***Project leader:*** Peter Gu, U of R.

**Detection and Reuse of Chemicals in Chemical EOR**
***Aim:*** To reduce the capital cost and environmental impact of chemical floods. ***Highlights:*** Corefloods showed that it is feasible to recover and re-inject produced chemicals. ***Status:*** Completed. ***Project leader***: Peter Gu, U of R.

**Selective Permeability Reduction by Polyacrylamide Polymers for Sask. Reservoirs**
***Aim:*** To enable oil companies to improve oil production by reducing water production, through polyacrylamide injection to selectively reduce permeability. ***Highlights***: Promising results from tests in cores and sandpacks showed that this process could reduce water production without adversely affecting oil production. ***Status:*** Nearing completion; seeking industry partner for field test. ***Project leader***: Koorosh Asghari, U of R.

## *Selected SRC Energy Division Publications*

***Determining the Most Profitable ASP Flood Strategy for Enhanced Oil Recovery,*** Zhang, Y.P., Huang, S. (SRC), and Dong, M. (U of R): paper presented at the Canadian International Petroleum Conference, Calgary, AB (June 10-12, 2003).

***Low-Temperature Oxidation of Oils in Terms of SARA Fractions: Why Simple Reaction Models Don't Work,*** Freitag, N.P. and Verkoczy, B.: paper presented at the Cdn. Intern. Petrol. Conf., Calgary, AB (June 10-12, 2003).

***Towards the Improvement of the Efficiency of Oil Sands Froth Treatment,*** Romanova, U.G., Yarranton, H., Schramm, L.L.: paper presented at the Cdn. Intern. Petrol. Conf., Calgary, AB (June 10-12, 2003).

***Treating Heavy Slop Oil with Variable Frequency Microwave,*** Renouf, G., Scoular, R.J., and Soveran, D.: paper presented at the Cdn. Intern. Petrol. Conf., Calgary, AB (June 10-12, 2003).

***Capillary Flow in Porous Media under Highly Reduced Gravity Investigated Through High Altitude Parabolic Aircraft Flights and NASA Space Shuttle Flight,*** Schramm, L.L., Wassmuth, F., Stasiuk, E., Hart, D., Legros, J.C., Smirnov, N.N.: *Proc*. Petroleum Society Cdn. International Petrol. Conf., Calgary, AB (June 10-12, 2003).

***Effect of Impurities in $CO_2$ on Gas-Injection EOR Processes,*** Huang, S. and Zhang, Y.P.: paper presented at the 24th Annual Workshop & Symposium, Collaborative Project on Enhanced Oil Recovery, International Energy Agency, Regina, SK (September 7-10, 2003).

***Improved Oil Recovery Science and Technology Priorities for Western Canada,*** Schramm, L.L., Jamieson, P.R., Moberg, R., Stewart, D.B.: *Proc.* 12th European Symposium on Improved Oil Recovery, Kazan, Tatarstan, Russia (Sept. 8-10, 2003).

***Filtration in Artificial Porous Media and Natural Sands under Microgravity Conditions***, Smirnov, N.N., Legros, J.C., Nikitin, V.F., Istasse, E., Schramm, L.L., Wassmuth, F., and Hart. D.: *Microgravity Science & Technology,* 14 (2003) 3-28.

***Surfactants and Their Applications,*** Schramm, L.L., Stasiuk, E.N., and Marangoni, D.G.: *Ann. Rep. Prog. Chem. Sect. C. Vol. 99*, 2003.

***Temperature Effects in the Conditioning and Flotation of Bitumen from Oil Sands in Terms of Oil Recovery and Physical Properties,*** Schramm, L.L., Stasiuk, E.N., Yarranton, H., Maini, B., and Shelfantook, B.: *J. Can. Petrol. Technol.*, 42 (2003) 55-61.

***Waste $CO_2$ Can Add Business Value,*** Schramm, L.L.: *Saskatchewan Business,* 24 (2004) 9.

***Technology Evaluation of BK Gasification Process,*** Soveran, D.W. and Ranganathan, R.: SRC Publication No. P-110-622-C-03.

***Laboratory Dynamic Fluid Testing – Reservoir Fluid Changes Over the Year 2002 (Task 5.2),*** Freitag, N.P. and Huang, S.: IEA Weyburn $CO_2$ Monitoring and Storage Project, SRC Publication No. P-110-626-C-03.

***Re-Injection of Recycled $CO_2$: Changes to $CO_2$–Oil Miscibility over the Year 2002 (Task 5.3.1),*** Freitag, N.P. and Huang, S.: IEA Weyburn $CO_2$ Monitoring and Storage Project, SRC Publication No. P-110-627-C-03.

***Depolymerization of Cellulose for Ethanol Fermentation,*** Jackson, C., Doerksen, K., Hyrsak, L. and Huntley, F.: SRC Publication No. P-110-639-C-04.

***Alkaline/Surfactant/Polymer Flooding for Southwest Saskatchewan Medium Oil Reservoirs, Final Report,*** Zhang, P., Sayegh, S., Huang, S., and Hutchence, K.: SRC Publication No. P-110-640-C-04.

***Enhanced Oil Recovery by Flue Gas/$CO_2$ Huff and Puff in Saskatchewan Reservoirs, Final Report,*** Zhang, P., Sayegh, S., and Huang, S.: SRC Publication No. P-110-643-C-04.

***Cyclic Solvent Stimulation of Horizontal Wells, Final Report,*** Freitag, N.P.: SRC Publication No. P-110-646-C-04.





## *Selected University of Regina Publications*

***Adsorption–Desorption-Related Interfacial Tension Behavior in Chemical Flooding and Its Effect on Oil Recovery,*** Liu, Q., Dong, M., Zhou, W., Ayub, M. (U of R), Zhang, Y.P., and Huang, S. (SRC): paper presented at the Petroleum Society Canadian International Petroleum Conference, Calgary, AB (June 10-12, 2003).

***A Novel Study of Electromagnetic Heating of Fluids in Porous Media for Preventing Deposition of Heavy Hydrocarbon Molecules,*** Asghari, K. and Sheidaei, M.: paper presented in the 53rd Canadian Chemical Engineering Conference, Hamilton, ON, October 26-29, 2003.

***Application of A Novel Polymer System in Chemical Enhanced Oil Recovery (EOR),*** Wang, W., Liu, Y., and Gu, Y.: *Colloid & Polymer Sci.*, 281, No. 11 (2003) 1046-1054.

***Applications of Weak Gel for In-Depth Profile Modification and Oil Displacement,*** Wang, W., Liu, Y., and Gu, Y.: *J. Can. Pet. Technol.*, 42, No. 6 (2003) 54-61.

***Effect of Sodium Dodecyl Benzene Sulfonate on Water-Soluble Hydrophobically Associating Polymer Solutions,*** Zhou, W., Guo, Y., Dong, M., and Xiao, H.: *J. Cdn. Pet. Tech.*, 43, No. 2 (2003) 13-16.

***Integrated Optimization and Control of the Production-Injection Operation Systems for Hydrocarbon Reservoirs,*** Yang, D., Zhang, Q., and Gu, Y.: J. *Pet. Sci.& Eng*., 37 (2003), 57-69.

***Development of an Artificial Network Model for Predicting Minimum Miscibility Pressure in $CO_2$ Flooding,*** Huang, Y.F., Huang, G.H., Dong, M.Z., and Zeng, G.M.: *J. of Pet. Sci. and Eng*., 37 (2003) 83-95.

***The Effects of Capillary Force and Gravity on the Interfacial Profile in a Reservoir Fracture or Pore,*** Gu, Y. and Yang, C.: *J. Pet. Sci. & Eng*., 40 (2003) 77-87.

***Displacement Optimization in Hydrocarbon Reservoirs,*** Yang, D., Zhang, Q., Gu, Y., and Li, L.: *Pet. Tech.*, January 2004, 45-46 (a non-refereed journal paper).

***Improved Oil Recovery by Adsorption–Desorption in Chemical Flooding,*** Liu, Q., Dong, M., Zhou, W., Ayub, M., Zhang, Y.P., and Huang, S.: *J. Pet. Sci. & Eng.* 43 (2004) 75-86.

***Development of a Statistical Model for Solvent-Aided Waterflooding,*** Ogunberu, A. and Asghari, K.: *J. Sci. & Tech*., 21 (2003) 1851-1866.

### *Accepted for publication or in press:*

***Effect of Operation Parameters on the $CO_2$-Foam Process,*** Asghari, K. and Khalil, Faisal: *J. Pet. Sci. & Tech.*, accepted.

***Immiscible Displacement in the Interacting Capillary Bundle Model: Part I — Development of Interacting Capillary Bundle Model,*** Dong, M., Dullien, F.A.L., and Dai, L.: *Transport in Porous Media*, in press.

***Immiscible Displacement in the Interacting Capillary Bundle Model: Part II — Applications of Model and Comparison of Interacting and Non-Interacting Capillary Bundle Models,*** Dong, M., Dullien, F.A.L., and Dai, L.: *Transport in Porous Media*, in press.

***Solubility and Density Measurement of Aqueous $CO_2$ Solution Under Reservoir Conditions,*** Li, Z., Dong, M., Li, S., and Dai, L.: *Journal of Chemical Engineering Data*, in press.

***Comparison of Three Models Used in the Experimental Measurement of Solvent Diffusivity in Heavy Oil,*** Tharanivasan, A. K., Yang, C., and Gu, Y.: *J. Pet. Sci. & Eng*., in press.

***Electrokinetic Effects on Flow of Aqueous Solutions through Microchannels,*** Gu, Y.: *Int. J. Transport Phenomena* (2004) in press.

***The Role of Wettability in Petroleum Recovery,*** Ogunberu, A.L. and Ayub, M.: *Pet. Sci. & Tech*., accepted.

***Experimental Testing of Interfacial Coupling in Two-Phase Flow in Porous Media,*** Ayub, M. and Bentsen, R.G.: *Pet. Sci. & Tech*., accepted.

Petroleum Technology Research Centre Inc.

# Auditor's Report

*To the members of Petroleum Technology Research Centre Inc.*

We have audited the statement of financial position of Petroleum Technology Research Centre Inc. as at March 31, 2004 and the statements of operations and unrestricted net assets and cash flows for the year then ended. These financial statements are the responsibility of the Centre's management. Our responsibility is to express an opinion on these financial statements based on our audit.

We conducted our audit in accordance with Canadian generally accepted auditing standards. Those standards require that we plan and perform an audit to obtain reasonable assurance whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation.

In our opinion, these financial statements present fairly, in all material respects, the financial position of the Centre as at March 31, 2004 and the results of its operations and cash flows for the year then ended in accordance with Canadian generally accepted accounting principles.

The previous year's financial statements were audited by other accountants.

REGINA, Saskatchewan
May 31, 2004

Virtus Group LLP
Chartered Accountants



Petroleum Technology Research Centre Inc.

# Statement of Financial Position

*as at March 31*

Statement A

| | General Operating Fund | Capital Fund | Weyburn Project Fund | 2004 Total | 2003 Total |
|---|---|---|---|---|---|
| **ASSETS** | | | | | |
| **CURRENT ASSETS** | | | | | |
| Cash | $ 32,845 | $ - | $ 77,057 | $ 109,902 | $ 427,097 |
| Accounts receivable | 1,373,492 | - | 873,602 | 2,247,094 | 1,980,582 |
| Prepaid expenses | 625 | - | - | 625 | 3,349 |
| | 1,406,962 | - | 950,659 | 2,357,621 | 2,411,028 |
| **PROPERTY, PLANT & EQUIPMENT** - Note 3 | 18,045 | - | - | 18,045 | 10,347 |
| | $ 1,425,007 | $ - | $ 950,659 | $ 2,375,666 | $ 2,421,375 |
| **LIABILITIES AND NET ASSETS** | | | | | |
| **CURRENT LIABILITIES** | | | | | |
| Accounts payable and accrued liabilities | $ 1,261,210 | $ - | $ 977,893 | $ 2,239,103 | $ 2,116,346 |
| **DUE TO (FROM) OTHER FUNDS** - Note 7 | 120,085 | (92,851) | (27,234) | - | - |
| **DEFERRED REVENUE** | | | | | |
| - Note 4 | 15,167 | 92,851 | - | 108,018 | 547,161 |
| | 1,396,462 | - | 950,659 | 2,347,121 | 2,663,507 |
| **NET ASSETS** | | | | | |
| Internally restricted - Note 8 | 48,750 | - | - | 48,750 | - |
| Unrestricted - Statement B | (20,205) | - | - | (20,205) | (242,132) |
| | 28,545 | - | - | 28,545 | (242,132) |
| | $ 1,425,007 | $ - | $ 950,659 | $ 2,375,666 | $ 2,421,375 |

*See accompanying notes*

Approved by the Board

Director

Director

Petroleum Technology Research Centre Inc.

## *Statement of Operations and Unrestricted Net Assets*

*For the year ended March 31*

Statement B

| | General Operating Fund | Capital Fund | Weyburn Project Fund | 2004 Total | 2003 Total |
|---|---|---|---|---|---|
| **REVENUE** | | | | | |
| **Annual Funding** | | | | | |
| - Saskatchewan Industry & Resources | $ 1,500,000 | $ - | $ - | $ 1,500,000 | $ 250,000 |
| - Natural Resources Canada | 1,000,000 | - | - | 1,000,000 | 875,811 |
| - Western Economic Diversification | 249,682 | | | 249,682 | - |
| **Project Funding** | | | | | |
| - Saskatchewan Industry & Resources - Note 4 | - | 137,149 | - | 137,149 | 855,000 |
| - Natural Resources Canada | - | - | 1,445,755 | 1,445,755 | 1,583,333 |
| - Natural Resources Canada and US Department of Energy | - | - | 2,556,876 | 2,556,876 | 1,949,597 |
| - Industry | 347,994 | - | 915,306 | 1,263,300 | 1,794,278 |
| **Interest** | 336 | - | (160) | 176 | 25,886 |
| **Other** | 485 | - | - | 485 | 650 |
| | 3,098,497 | 137,149 | 4,917,777 | 8,153,423 | 7,334,555 |
| **OPERATING EXPENSES** | | | | | |
| Amortization | 4,185 | - | - | 4,185 | 3,182 |
| Conferences | 26,665 | - | - | 26,665 | 8,219 |
| Consulting | 227,782 | - | - | 227,782 | 261,784 |
| Dues and subscriptions | 9,952 | - | - | 9,952 | 2,271 |
| Financial systems support | 121,013 | - | - | 121,013 | 10,576 |
| Insurance | 8,042 | - | - | 8,042 | 6,671 |
| Legal and audit | 8,302 | - | - | 8,302 | 6,438 |
| Materials and supplies | 3,874 | - | - | 3,874 | 4,911 |
| Office and administration | 60,573 | - | - | 60,573 | 24,842 |
| Other | 3,837 | - | - | 3,837 | 4,519 |
| Publications and promotion | 44,853 | - | - | 44,853 | 51,628 |
| Rent | 63,775 | - | - | 63,775 | 48,566 |
| Salaries and benefits | 113,771 | - | - | 113,771 | 278,578 |
| Travel | 84,896 | - | - | 84,896 | 20,668 |
| | 781,520 | - | - | 781,520 | 732,853 |
| **PROJECT EXPENSES** - Note 5 | 2,046,300 | 137,149 | 4,917,777 | 7,101,226 | 6,565,002 |
| **EXCESS OF REVENUE** | 270,677 | - | - | 270,677 | 36,700 |
| **UNRESTRICTED NET ASSETS** - beginning of year | (242,132) | - | - | (242,132) | (378,832) |
| **(RESTRICTIONS)/ REVERSALS** - Note 8 | (48,750) | - | - | (48,750) | 100,000 |
| **UNRESTRICTED NET ASSETS** - end of year - Statement A | $ (20,205) | $ - | $ - | $ (20,205) | $ (242,132) |

*See accompanying notes*



Petroleum Technology Research Centre Inc.

## *Statement of Cash Flows*

*For the year ended March 31*

Statement C

| | 2004 | 2003 |
|---|---|---|
| **OPERATING ACTIVITIES** | | |
| Excess of revenue | $ 270,677 | $ 36,700 |
| Item which does not affect cash outlay: - amortization | 4,185 | 3,182 |
| | 274,862 | 39,882 |
| Net change in current assets | (263,788) | 960,302 |
| Net change in current liabilities | 122,757 | (158,995) |
| Net change in deferred revenue | (439,143) | (979,278) |
| **Net cash from operating activities** | **(305,312)** | **(138,089)** |
| **INVESTING ACTIVITIES** | | |
| Purchase of equipment | (11,883) | - |
| **Net cash used by investing activities** | **(11,883)** | - |
| **DECREASE IN CASH RESOURCES** | **(317,195)** | **(138,089)** |
| **CASH** - beginning of year | 427,097 | 565,186 |
| **CASH** - end of year | $ 109,902 | $ 427,097 |
| **REPRESENTED BY:** Cash balance in chequing accounts | $ 109,902 | $ 427,097 |

*See accompanying notes*

## 1. NATURE OF ORGANIZATION

The Centre is an internationally recognized innovative leader in the petroleum research and development area that delivers world-class basic and applied research for the benefit of the people of Saskatchewan, Canada and their customers around the globe. The Centre is incorporated under the Canada Business Corporations Act as a non-profit corporation and is exempt from income taxes on its income.

## 2. SIGNIFICANT ACCOUNTING POLICIES

These financial statements are prepared in accordance with Canadian generally accepted accounting principles and the most significant policies are as follows:

**Fund Accounting**

The accounts of the Centre are maintained in accordance with the principles of fund accounting. For financial reporting purposes, accounts with similar characteristics have been combined into the following major funding groups:

**i) General Operating Fund**

The operating fund reflects the primary operations of the Centre including revenues received from Saskatchewan Industry & Resources and the Department of Natural Resources Canada to fund its daily operations and administration activities.

**ii) Capital Fund**

The capital fund reflects the commitment of the Government of Saskatchewan to assist in funding a Petroleum Research Building on the campus of the University of Regina as well as the acquisition of equipment to be used by the University of Regina, the Saskatchewan Research Council and the Centre. While the Centre does have access to the use of the equipment and building, they do not maintain ownership rights and all acquisitions are expensed in the year incurred.

The Government of Saskatchewan provided this funding through Saskatchewan Industry & Resources.

**iii) Weyburn Fund**

The Weyburn fund reflects the funding received from government and industry and expenditures made for the IEA Weyburn $CO_2$ monitoring project.





**Revenue Recognition**

The Centre follows the deferral method of accounting for contributions. Restricted contributions related to general operations are recognized as revenue of the operating fund in the year in which the related expenses are incurred. All other restricted contributions are recognized as revenue of the appropriate restricted fund.

Unrestricted contributions are recognized as revenue of the operating fund in the year they are received or receivable if the amount to be received can be reasonably estimated and collection is reasonably assured.

**Property, Plant and Equipment**

These assets are stated at cost and are amortized using the declining balance method at the rates indicated in Note 3. One-half year's amortization is recognized in the year of acquisition.

**Use of Estimates**

The preparation of financial statements in accordance with Canadian generally accepted accounting principles requires management to make estimates and assumptions that affect the reported amount of assets and liabilities and disclosure of contingent assets and liabilities at the date of the financial statements and the reported amount of revenues and expenses during the reported period. Since actual results may differ from the estimates, these estimates are reviewed periodically, and, as adjustments become necessary, they are reported in earnings in the period in which they become known.

## 3. PROPERTY, PLANT AND EQUIPMENT

| | 2004 Cost | 2004 Accumulated Amortization | 2004 Net Book Value | 2003 Net Book Value | Rates |
|---|---|---|---|---|---|
| Computers | $ 23,107 | $ 10,672 | $ 12,435 | $ 3,334 | 30% |
| Office furniture | 12,175 | 6,565 | 5,610 | 7,013 | 20% |
| | $ 35,282 | $ 17,237 | $ 18,045 | $ 10,347 | |

## 4. DEFERRED REVENUE

The Centre receives contributions from government and industry for specific projects. These funds are restricted in use as directed by the external sponsors. The Centre recognizes revenue for these projects on the same basis as expenditures are incurred. Any excess revenue in the year is deferred and recognized in future years as expenditures are incurred.

The Capital Fund reflected the commitment of the Government of Saskatchewan to assist in the funding of a Petroleum Research Building on the campus of the University of Regina. Of the $3,000,000 received, $2,600,000 was designated for equipment purchases and $400,000 was designated to partially fund building construction of the PTRC building (completed in 2000 - 01).

During the year, the Centre funded equipment expenditures of $137,149 (2003 - $855,000). At March 31, 2004, the balance of the Capital Fund - Deferred Revenue was $92,851 (2003 - $230,000).

The Centre funded Innovation and Incubation project expenditures of $226,994 (2003 - $517,839) during the year. As at March 31, 2004, the General Operating Fund - Deferred Revenue was $15,167 (2003 - $317,161).

## 5. PROJECT EXPENSES

During the year, the General Operating Fund incurred project expenses of $2,046,300 (2003 - $1,351,234).

| | 2004 | 2003 |
|---|---|---|
| Equipment projects | $ - | $ 127,065 |
| Innovation projects | 1,856,223 | 1,168,159 |
| Incubation projects | 190,077 | 56,010 |
| | $ 2,046,300 | $ 1,351,234 |

Equipment project expenditures are related to the purchase of new equipment for research providers that are involved in Innovation or Incubation projects for the Centre.

Innovation projects are designed to refine research output into actual field applications that may be used by the petroleum industry. These are usually medium to large sized projects with a timeline of more than one year.

Incubation projects are projects aimed at determining if a specific area of research has relevant applications in the petroleum industries. These projects are relatively small with a short time frame.

The Capital Fund expended $137,149 (2003 - $855,000) on funding equipment purchases for research providers to enhance core capabilities.

For details of the Weyburn Project Expenses, please refer to Schedule 1 of the financial statements.



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(continued)

## 6. ECONOMIC DEPENDENCE

The Centre has received funding commitments from Natural Resources Canada, Western Economic Diversification Canada and Saskatchewan Industry & Resources for the years 2004 through 2007 for research projects and operations:

| | |
|---|---|
| Natural Resources Canada | $4,000,000 over 4 years |
| Western Economic Diversification Canada | $1,000,000 over 4 years |
| Saskatchewan Industry & Resources | $5,000,000 over 4 years |

The Centre seeks additional funding for its research projects from both other federal sources and from the petroleum industry. Additionally, Saskatchewan Industry & Resources has committed to match approved supplemental federal funding up to a maximum of $1,000,000 over the same time frame.

## 7. DUE TO (FROM) OTHER FUNDS

The cash of all General Operating Fund and Capital Fund operations is combined for efficiency of operations. As of March 31, 2004, $92,851 (2003 - $230,000) is owing to the Capital Fund from the General Operating Fund. Although the cash for the Weyburn fund is separate from the General Operating Fund, payments made from one fund on behalf of the other are occasionally made and may be outstanding at year end.

## 8. NET ASSETS RESTRICTED FOR EXECUTIVE COMPENSATION

The Executive Director's terms of employment contain a clause for a compensation payout in the event that the Centre is unable to attract funding post-2007 and the Centre ceases operations. This date coincides with the time frame for the firm funding commitments listed in Note 6.

A restriction of net assets has been made of $48,750 to represent the potential risk-assessed cost. In the prior year, a reversal of $100,000 was recognized following the resignation of the General Manager. This assessment of risk and the calculation of the restriction will be reviewed by Management on an annual basis.

## 9. FINANCIAL INSTRUMENTS

**Fair Value of Financial Instruments**

The carrying amount of cash, current receivables and payables approximates their fair market value because of the short-term maturities of these items.

**Credit Risk**

The Centre does not believe it is subject to any significant concentration of credit risk on any of its customers.

## 10. COMPARATIVE FIGURES

Certain of the 2003 financial statement balances have been reclassified to conform to the current year's presentation.

# *Schedule of IEA Weyburn $CO_2$ Monitoring Project Fund*

*as at March 31*

Schedule 1

| | 2004 Cumulative Project-to-Date | 2004 Annual Activity | 2003 Annual Activity |
|---|---|---|---|
| **REVENUES** | | | |
| **Government** | | | |
| Natural Resources Canada | $ 5,930,000 | $ 1,445,755 | $ 1,583,333 |
| Natural Resources Canada and US Department of Energy | 4,506,474 | 2,556,877 | 1,949,597 |
| | 10,436,474 | 4,002,632 | 3,532,930 |
| **Industry** | | | |
| Alberta Environment | 225,000 | 75,000 | 75,000 |
| Alberta Science and Research Authority | 225,000 | 75,000 | ,75,000 |
| Chevron Texaco | 300,000 | 225,000 | 75,000 |
| Engineering Advancement Association of Japan | 300,000 | 75,000 | 75,000 |
| PTRC (General Operating Fund) | 105,000 | - | - |
| EnCana | 100,000 | - | - |
| Saskatchewan Industry & Resources | 105,000 | - | - |
| BGRM | 19,491 | 19,491 | - |
| SaskPower | 300,000 | 75,000 | 75,000 |
| BP (Amoco) | 300,000 | 70,814 | 75,000 |
| Transalta Utilities | 300,000 | 75,000 | 75,000 |
| Nexen Inc. | 300,000 | 75,000 | 75,000 |
| Dakota Gasification Company | 300,000 | 75,000 | 150,000 |
| Saskatchewan Petroleum Research Incentive | 2,062,720 | - | - |
| TOTAL (Totalfinaelf) | 300,000 | 75,000 | 75,000 |
| | 5,242,211 | 915,305 | 825,000 |
| Interest | 14,282 | (160) | 838 |
| | $15,692,967 | $ 4,917,777 | $ 4,358,768 |
| **EXPENDITURES** | | | |
| Task 1 – Collection of Field Data and Samples | $ 2,170,826 | $ 58,690 | $ 561,860 |
| Task 2 – Geoscience Framework | 2,559,271 | 1,365,355 | 964,512 |
| Task 3 – Geochemical Sampling, Monitoring & Prediction | 2,080,505 | 1,041,179 | 508,565 |
| Task 4 – Seismic Surveys | 4,407,700 | 473,709 | 962,672 |
| Task 5 – Sequestration Engineering | 2,742,508 | 1,301,844 | 823,427 |
| Task 6 – $CO_2$ Storage Economics | 118,938 | 57,864 | 49,689 |
| Task 7 – Project Control | 1,613,219 | 619,136 | 488,043 |
| | $15,692,967 | $ 4,917,777 | $ 4,358,768 |
| **ENDING FUND BALANCE** | $ - | $ - | $ - |

This schedule shows the cumulative funding and expenditures for the IEA Weyburn $CO_2$ Monitoring Project since its inception as well as the annual funding and expenditure activity for the years ended March 31, 2004 and 2003.

The Natural Resources Canada (NRCan) and US Department of Energy (US DOE) funding is a funding mechanism that is designed to cover expenses not funded by NRCan or industry resources. At year-end, the balance of unfunded expenditures is accrued as Accounts Receivable based on the contractual agreement with NRCan and US DOE.

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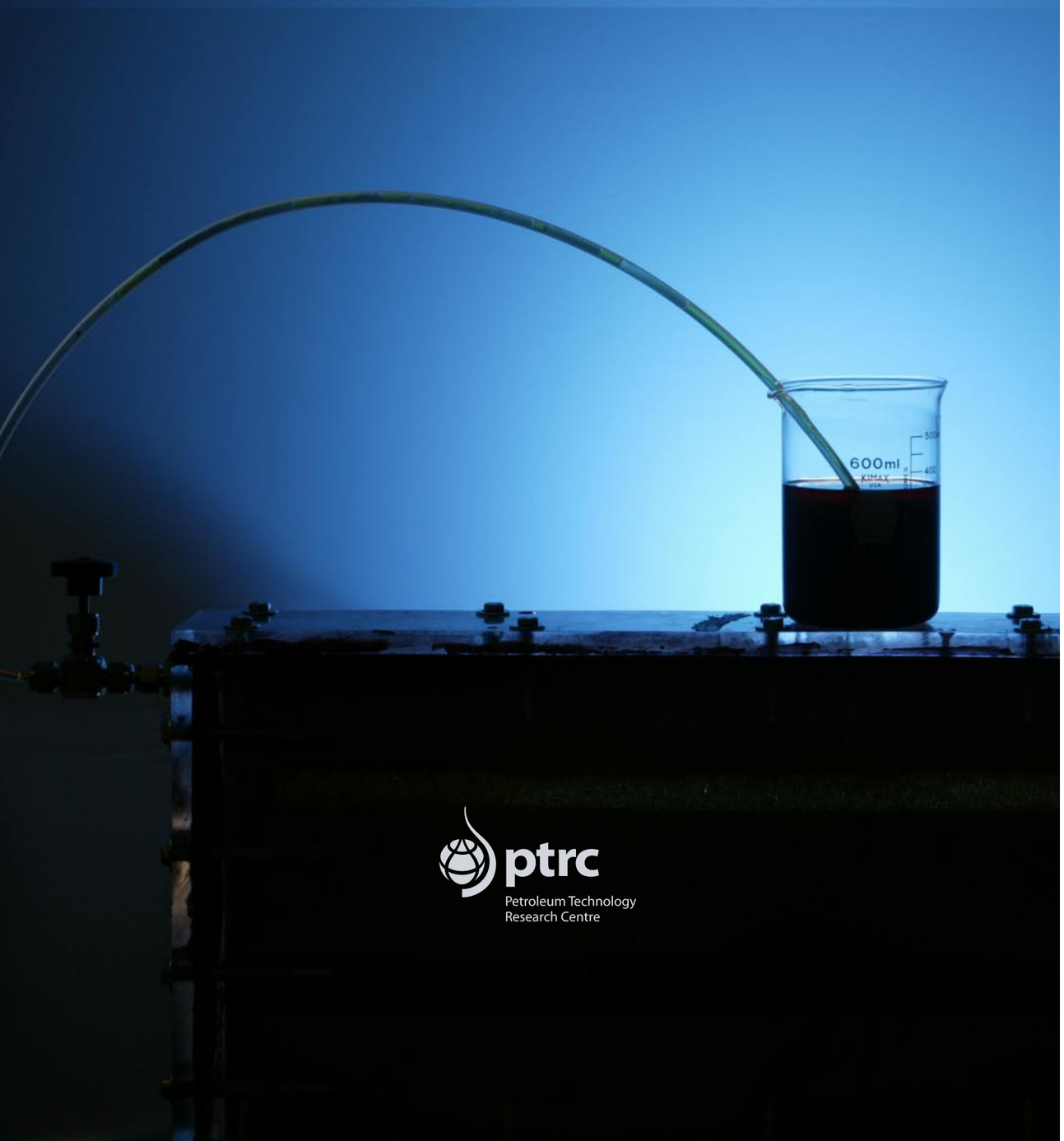


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