AlbertaVenture

Dawn of the Clean Oilsands

Vol. 12 Issue 8

Imagine the oilsands without tailings ponds, CO2-belching upgraders or even the need for water. Researchers working on future generations of oilsands technology are getting there – by thinking small
By Bruce White

As a boy growing up in Venezuela, Pedro Pereira Almao might easily have become a revolutionary. The son of a small-town family that moved to Caracas – his mother was a primary school teacher and his father a baker and labourer – Pereira Almao absorbed the communist ideals of his parents.

At university he was active in the student union, but it turned out that Pereira Almao excelled not at politics but in chemistry. He is now 53 years old, his youthful ideology mellowed by travel and learning. Five years ago, he departed the Venezuela of left-wing president Hugo Chavez for the corporate environment of Calgary. But make no mistake, Pereira Almao remains a revolutionary among chemical engineers.

For one thing, he believes heavy oil and bitumen can be upgraded in their natural underground reservoir with the help of nano-sized catalysts. Carbon-laden asphaltenes would be scavenged for their hydrogen and left underground. The harvested hydrogen would upgrade the bitumen to refinable oil in situ (literally, in place). Waste products such as sulphur, heavy metals and carbon dioxide could be left behind in depleted reservoirs, hundreds of metres below the ground.

If Pereira Almao's ideas prove out, a few pickup truckloads of equipment at a wellhead could one day do the work of the multibillion-dollar upgraders that are sprouting around Fort Saskatchewan and Wood Buffalo. His work, and that of a small cadre of scientists looking at the resource on a molecular level, could also make a substantial contribution to cleaning up the "tarsands" so vilified by environmental activists.

Pereira Almao admits his ideas sound fanciful. "When they started planning a trip to the moon, that was a real pie in the sky," he points out. "But they put the people together and they ended up achieving that."

Like the scientists at NASA 50 years ago, the soft-spoken Pereira Almao has the perfect opportunity to test his ideas. He is co-director of the Alberta Ingenuity Centre for In Situ Energy (AICISE), a high-powered idea factory established in 2004 at the University of Calgary. Working with more than 30 leading scientists and researchers, he is tasked with finding cleaner and more efficient ways to exploit Alberta's heavy oil and oilsands. The centre's cast of PhDs includes geologists, geophysicists and engineers with expertise in heavy oil recovery, reservoir imaging and modelling, among others.

Before arriving at the U of C in 2003, Pereira Almao worked and studied on three continents and in three languages to develop his specialty in petroleum catalysis – studying how crude oil "cracks" into smaller molecules of marketable products such as gasoline when it is heated and exposed to catalysts.

After reading about the free-enterprise solution to the coming water shortage ("Who Killed Water Markets?"), what do you think should happen?

- ◯ Maintain the current system – it works fine
- ◯ Reduce consumption via restrictions on industry and citizens
- ◯ Introduce water credits that can be bought and trade
- ◯ Nothing. The water shortage is totally overblown

Vote!

With a doctorate from the University of Poitiers in France, he returned home in the 1980s to become a professor of chemical engineering at the University of the Andes. He later became a senior researcher for PDVSA-Intevep, the national oil company of Venezuela. He also spent three years in advanced research at the renowned Lawrence Berkeley National Laboratory in California.

Pereira Almao is co-inventor of a process called Aquaconversion, in which steam and a catalyst extract hydrogen from low-value petroleum coke – a process that also works with bitumen. Working with new catalysts in his Calgary labs, he has dramatically reduced the cracking temperature while increasing the efficiency of the reaction. He has also shown in lab conditions that his nano-catalyst (he won't reveal what it is for competitive reasons) can be mixed with oil and dispersed through the packed sand and muck inside a bitumen deposit.

What Pereira Almao proposes one day could end up looking something like this: steam is injected to a reservoir to heat the bitumen to 200 C to initially get it flowing. A nano-catalyst, which might resemble sifted pastry flour, is mixed with oil and injected into the well, where it percolates through the warming bitumen. Automated chemical analysis at the wellhead reveals what is happening underground and allows a geologist 800 kilometres away in a Calgary office tower to monitor the well.

When conditions are ripe, a mouse click causes a small "hot zone" to be created by injecting oxygen to ignite a small amount of bitumen in the well. In this 450 C hot zone, conditions exist for steam and catalyst to crack hot bitumen into smaller molecules and take up hydrogen. Upgraded bitumen is pumped to the surface, cleaned and sent by pipeline directly to a refinery. As a bonus, heat escaping the hot zone liquefies more bitumen in the reservoir, eliminating the need to burn additional gas to make steam.

"We are creating a reactor. We are creating a zone that we can control. We can even control the size of it," Pereira Almao says. The next step is scaling up his research from the lab bench to a $22-million testing facility that is being built as an addition to the Calgary Centre for Innovative Technology building at the U of C.

Steve Larter, who with Pereira Almao is a co-director of the in situ centre, is a petroleum geologist who came to Calgary in 2004 from Newcastle University in the United Kingdom. Like Pereira Almao, Larter has a multinational resumé: born in the Fens of England; visi-ting professor in Norway; and senior research geochemist for Unocal in the United States. He is well aware of the challenges of working in the underground environment of an in situ well.

"These reservoirs aren't like homogeneous tanks of sand. They have shale, they've got faults and they're basically very complicated," Larter explains. Even within one well, bitumen can be up to 30 times more viscous at the bottom of a deposit than at the top.

Another problem in the underground environment is visibility. Drilling a core sample tells precisely what's down there, but only at one place and only in a sample a few inches in diameter. For the big picture, you need to look at seismic data, which is very low-resolution and doesn't see anything much smaller than a house. Trying to connect the dots to make an accurate geophysical map of the whole area is a real art.

A further issue with in situ upgrading is instrumentation. It's one thing to put a pressure gauge on a tank or a flow meter on a pipe but quite another to get an accurate picture of conditions hundreds of metres below your feet. Researchers at the centre are investigating reliable ways of knowing what's going on in a well based on instant chemical analysis of the bitumen as it is pumped to the surface.

"We're looking at molecular ways of telling what reactor conditions would be like, what the temperatures and pressures and catalytic conditions are in the subsurface," Larter explains.

Larter's interests also include the emerging area of petroleum biotechnology (Alberta Venture, April 2008, p. 92). This summer, he is to begin a field experiment in a Lloydminster-area producing well to fertilize naturally occurring microbes and harness their process of turning unrecovered heavy oil into methane. Tests will reveal within three to five years whether speculative ideas such as in situ upgrading and fermenting gas from leftover oil will succeed, Larter says. “It’s high-risk – it’s hard enough to get steam to go though a reservoir, let alone catalysts and microbes – but the payoff is colossal.”

Alberta Ingenuity, a billion-dollar provincial research endowment, is funding AICISE along with the federal government. Corporate sponsors include Royal Dutch Shell and Calgary-based producer Nexen Inc., which will host the Lloydminster test.

“Nexen is very excited about break through, game changing potential of the AICISE in situ upgrading technology,” says Patrick Jamieson, a chemist trained at the University of Alberta and UBC who is charge of research and development at Nexen. “It is certainly a much more environmentally friendly process, and since you are doing less upgrading on the surface you will have less emissions and less capital cost.”

Peter Hackett, president and CEO of Alberta Ingenuity, adds that Alberta companies will be the first to benefit from rolling out third and fourth generation oilsands technologies and will gain a first-mover advantage in deploying them around the world. “You can expect to see more efficient processes, using less gas, less water and creating less waste products – at less cost to produce,” Hackett enthuses.

While AICISE focuses on the in- situ side of the industry, a sister operation at the University of Alberta is investigating processes related to surface-mined oilsands. The Imperial Oil-Alberta Ingenuity Centre for Oil Sands Innovation (COSI) is researching a suite of technologies to improve the sustainability of the oilsands. These include looking for more efficient ways to extract the good components of bitumen, “non-aqueous extraction” techniques that don’t use any water to produce bitumen and which would eliminate giant tailings ponds, and low-impact mining in the mid-level regions too deep for bucket and shovel and too shallow for steam injection.

As with the U of C operation, the study of catalysts plays an important role. In the 1960s-era Chemical and Materials Engineering Building at the U of A, Steven Kuznicki, an affable former researcher in New Jersey’s giant chemical industry, exudes enthusiasm for molecular sieves, which act much like a window screen that keeps out mosquitoes while allowing fresh air to flow into the house. Molecular sieves remove lead from drinking water, an application that Kuznicki helped to pioneer. (Kuznicki is also using molecular sieves to cheaply manufacture nano-silver, a natural infection fighter, but that’s a story for another day.) They are used in cracking petroleum and as an energy-saving alternative to liquefying gases for separation.

Kuznicki is investigating a water-free method of upgrading bitumen in situ by mixing it with a molecular sieve, then heating the mixture. The molecular sieve acts as a catalyst to separate sand and other undesirables from the bitumen. When it has done its job, the mineral sieve is cheap enough to be entombed hundreds of metres below the northern Alberta moose pasture with the bad stuff stuck to it after the marketable oil is dissolved in light hydrocarbons and piped away.

The work of Kuznicki and his colleagues is a continuation of oilsands research at the University of Alberta that began in the 1920s when Karl Clark investigated possible uses for bitumen from the Athabasca region. It is also an extension of 20 years of modern oilsands research for Imperial Oil at the U of A. “Unlike the rest of the world, we never forgot about the oilsands,” says COSI director Murray Gray, a Toronto native who got his PhD from Cal Tech. “My colleagues and I were working with the industry all through the 1980s and 1990s long before the industry took off.”

And like Clark – whose work wasn’t realized until Suncor opened in 1967 – Gray and most others in oilsands research have their eye on the long term. “The reality is that if we come up with an interesting idea, it would take many years and tens of millions of dollars to prove it to the point [whereupon] it could be commercialized,” says Gray.

No matter how long it takes, finding a cleaner way to produce oil from the oilsands is important, and not only for the future of Alberta. The world depends on oil to grow enough food, to move goods across oceans and continents and to provide people with the easy mobility that makes us happier and more productive. Few people will be willing to give up oil any time soon. With light oil in politically stable places becoming increasingly scarce, Alberta and other heavy oil and bitumen sources will become more important. Therefore, it is imperative to remove the environmental objections to the "tarsands" so vividly illustrated by the death of migratory waterfowl at a Syncrude Canada Ltd. tailings pond last April.

"I just look at the size of the resource and the potential for that resource if we can develop more sustainable technology," says Gray. "We can certainly improve how we use that resource in terms of environmental performance."

A Heavy Oil Glossary

Asphaltenes – Heavy, complex hydrocarbons found in oil, but in progressively greater amounts in heavy oil and bitumen.

Bitumen – A semi-solid, degraded crude oil that is mixed with sand and clay in the Alberta oilsands.

Catalyst – A material such as a rare metal that in small amounts stimulates a chemical reaction without being consumed itself.

Heavy oil – Petroleum that is thought to have been degraded by microbes in the reservoir; commercially produced in eastern Alberta and western Saskatchewan.

Molecular sieve – Clays such as zeolite and many other mineral and synthetic substances that are used to separate materials by allowing smaller molecules to pass through precisely sized holes in their structure; can also act as a catalyst.

Nanomaterials – A sub-sector of nanotechnology that exploits the properties of extremely small particles, including their ability to be dispersed.

SAGD – Steam assisted gravity drainage is the most common method for recovering heavy oil or bitumen in situ (or "in place"). Consists of two parallel wells: one injects steam to heat and liquefy the resource, the other to pump it to the surface.

Upgrader – Refinery-like plant that upgrades heavy oil or bitumen into synthetic crude oil by removing excess carbon molecules and adding hydrogen, while also removing undesirable metals and sulphur compounds.