

Next*

* Chevron Technology

New Energy Horizons

Diversifying our energy sources for tomorrow



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On the Cover

Energy is vital, and energy is our business. As the stories in this issue show, Chevron's approach to energy technology embraces innovative solutions. From advancing technologies for capturing and transforming traditional energy sources to developing emerging energy technologies, Chevron is on the forefront of this vast exploration. We welcome the challenge of helping meet the world's need for energy—now and for the future.



Next*

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Our industry has always been driven by technology. But more than 30 years ago when I joined the company, I would not have expected to one day find myself representing Chevron at the U.S. Department of Agriculture for a recent meeting on biofuels.

The convergence of interests of global energy companies, such as Chevron, and governments on the advancement of emerging energy sources illustrates the growing scope of a vital trend: the needed diversification of energy sources. To meet global energy demand, every molecule counts, and the world will need a contribution from every potential type and source of energy.

Advanced technology offers the key to unlock the energy needed to sustain development in emerging economies and to continue growth in developed economies. Within this second issue of *Next**, we illustrate Chevron's approach to technology

applied in imaginative and innovative ways to produce energy and improve lives.

We offer our customers access to new resources and help them capture greater value from their existing resources. In Millbrae, California, for example, Chevron installed technology allowing the city's wastewater treatment plant to use daily deliveries of restaurant kitchen grease to generate biogas and renewable power.

In our own operations, we have continually been reducing the conventional energy we use in production. In the San Joaquin Valley, where we have long used solar power to generate electricity, we are studying a solar-to-steam demonstration project to generate the steam Chevron uses in enhanced recovery that makes heavy oil easier to extract. This initiative is just one of a number of steps Chevron is taking to create new energy sources, increase efficiency and lower greenhouse gas emissions.

New technologies are being applied to our operations worldwide. Our joint venture in Kazakhstan has a massive operation to reinject the high-pressure hydrogen sulfide gas, which will increase production at the giant Tengiz Field.

In other applications, our scientists have developed a new treatment for arsenic-contaminated drinking water. And Chevron lubricants experts designed a solution to help a "sky train" in China operate safely in remote locations under the hazardous conditions of extremely high altitudes and low temperatures.

Finally, collaboration and partnership are essential to our approach to technology. In this issue, we discuss key partnerships Chevron has launched with universities, government research institutions and industry to develop technologies to convert cellulosic biomass into transportation fuels.

I hope you enjoy learning more about the ways that Chevron technology is benefiting people around the world and expanding the global energy portfolio.

Sincerely,

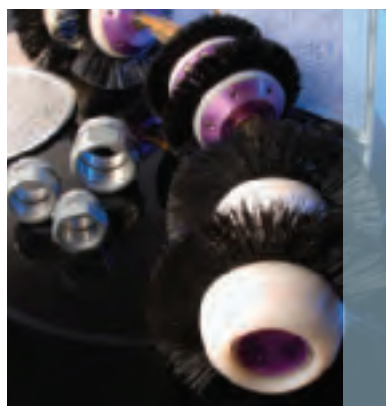
Don Paul

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* Here and Now

Out-of-the-Pipe Thinking

Refining's 360-degree technology vision



On the front lines of Chevron Global Refining's Open Innovation program, the Richmond, California, refinery conducts inspections with technology-packed "intelligent pigs." The units crawl through thousands of feet of narrow furnace tubes and quickly transmit detailed data and digital images that detect weak spots, corrosion, bulging and other irregularities, thus facilitating early repair.

They look like strange toys, with fuzzy fins and colorful minimodules linked by delicate cables—but Chevron Global Refining has a serious mission for these high-tech charmers: inspect high-temperature furnaces from the inside and find corrosion before it causes an incident.

Pushed by water pressure, the "intelligent pigs" wriggle through thousands of feet of narrow tubes during maintenance downtimes, scouting conditions inside hydrotreaters, reboilers and other massive facilities that operate at up to 900 degrees Fahrenheit (482 C).

"No conventional inspection could find this," says Ashok Krishna, Refining's technology manager, pointing to a red spot in a zigzagging image created by a pig's 1,260 readings per foot. "We're looking at fantastic potential to support incident prevention and reliability."

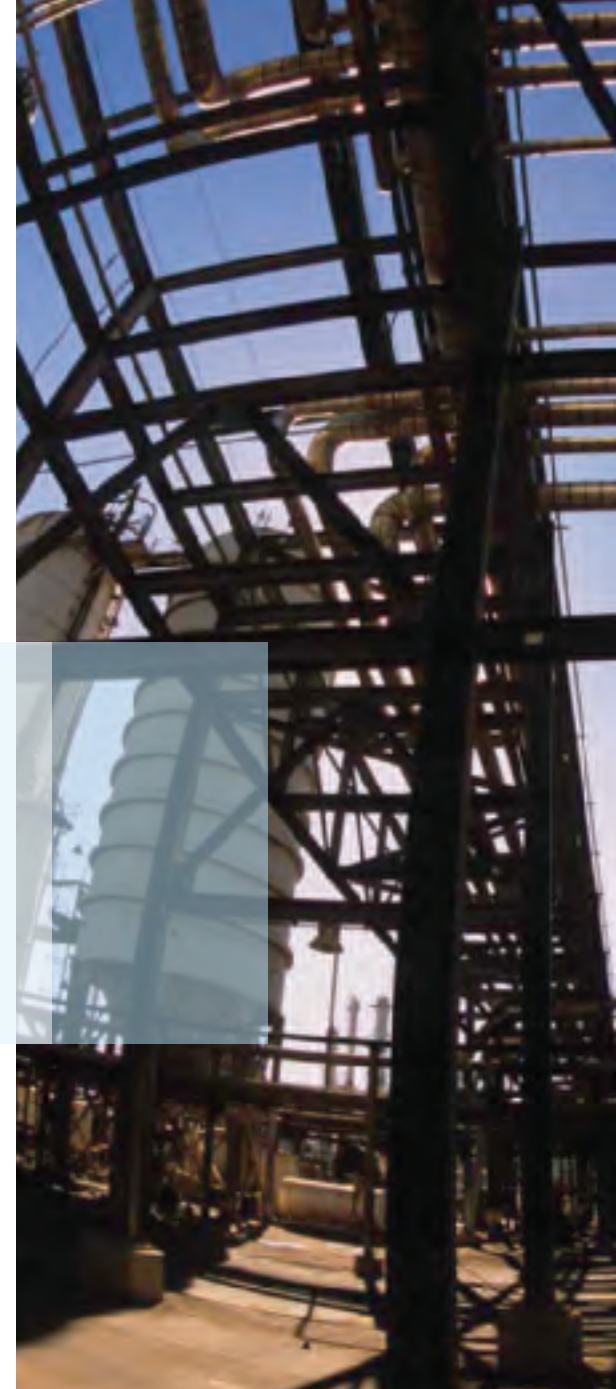
In fact, the piglets found undetected tube concerns in four locations last year, says Neil Ruegsegger, a refinery reliability team leader. Now he's preparing a master database of furnaces so Chevron can put this technology to work systemwide.

Open Innovation

This is just one example of Open Innovation, a two-year-old initiative that searches far and wide for new refinery technology. The initiative is focused mainly on Refining's base business, the around-the-clock operations that process crude oil into millions of gallons of fuels every day. It's all about reliability and efficiency, and Open Innovation so far has identified some 30 technologies for assessment, pilot testing, possible co-development and potential use throughout Chevron's worldwide network of 20 fuel refineries.

"Getting better ideas into your business faster than competitors on a sustained basis can give you a real competitive edge," says Jim Whiteside, Refining's vice president for planning and development.

Chevron's approach also has the potential advantage of free access to new technologies it co-funds and commercializes with small companies, plus potential profits from future sales of jointly owned, proprietary technologies, says Krishna.



Sniffing Out Prospects

Ron Wright, who works on Open Innovation, says Refining screens three to four prospects a month. He recently visited the Pacific Northwest National Laboratory to check out their work in process equipment monitoring, solid-fuel gasification and viscosity reduction, which make crude oil easier to transport.

Some prospects walk in the door, others must be discovered and many have yet to ripen into useful technologies, says Wright. "There are a lot of small businesses that don't know how to take an idea through the stages of commercialization to create a product. I'm convinced that the more we look, the more we'll find."



Chlorides, Vapors

Consider the chloride analyzer that was developed with a third party. It detects the tiniest amounts of these pesky impurities in refinery streams so that engineers can plan ahead to keep them from causing problems. Another company has invented a device that sees invisible vapor leaks and alerts operators to pollution and hazards.

“When you find natural fits between new technologies and refineries, you can expect a better than 50 percent success rate,” says Whiteside.

Another invention uses light to neutralize pollutants in furnace stacks, which is more cost-effective than using catalysis or heat for the same job.

Refinery-Friendly Approach

Using outside technology is nothing new at Chevron. But with Open Innovation—designed with advice from Chevron’s own technology businesses—Refining is becoming systematically more aggressive in its pursuit of better tools.

The process addresses the special needs of inventors and small companies. Says Krishna: “Often, they have something clever but need help and money, so we provide funding to test low-risk, potentially high-reward technologies.”

Also, Open Innovation is designed to succeed within Refining’s business culture. Instead of burdening refineries with research and development costs, funding comes from a central budget. Technology prospects are matched to refineries’ business needs. And especially important, says Krishna, tests are designed to not interrupt operations.

Knock on Chevron’s Door

Open Innovation’s vision is for Refining to become known as the preferred partner for external opportunities and the company that implements new technology faster.

The enthusiastic Krishna can see it now: “We aim to have vendors clamoring for our attention. Those with great ideas will want to knock on Chevron’s door first.”

New Tech Centers Increase Global Reach

Chevron opens energy technology centers in Aberdeen and Perth

As the exploration for oil and gas in the North Sea and Southeast Asia continues, Chevron strengthens its ties to the regions. Subsidiary Chevron Energy Technology Co. (ETC) recently opened two new technology centers—one in Aberdeen, Scotland, and the other in Perth, Australia. ETC provides strategic research and

technology development as well as technical services to Chevron’s upstream, downstream, gas and emerging energy businesses around the world.

The new facilities, complementing the company’s two existing major technology centers in the United States, will enhance the company’s ability to serve its opera-

tions worldwide, work with regional R&D partners and attract in-country and regional talent.

“This step will help us expand Chevron’s technology capabilities and increase our worldwide access to technical talent,” says Mark Puckett, ETC president. “Not only will the technology output of these new centers apply

to the business we’re pursuing in the respective regions, we plan to apply the technologies and knowledge from these new centers to Chevron’s operations globally.”

The centers will work in collaboration with the local business units to develop and manage relationships with internal and external stakeholders.

“Regional input, global output” is how Paul Jones, Perth technology center manager, describes Chevron’s strategy. “We can now tap into a wealth of capability and technology development opportunities in the Asia-Pacific region to deliver technology to Chevron’s global businesses,” he says.

Portable Potability

Unearthing solutions to a worldwide water problem

The Mojave Desert between Los Angeles and Las Vegas is home to unique geologic features. Some, however, only a trained eye is likely to notice, such as the roadside vein of magmatic material that pushed its way to the surface in Mountain Pass, California, 500,000 years ago. Today, this site is one of the richest rare-earth deposits in the world—and home base to a budding technology development center for Molycorp, Inc., a Chevron mining and technology development company.

Rare earths, also known as lanthanides, are commercially available in only one other location: China. In their pursuit of new applications for these elements, Molycorp chemists have discovered a new way to treat arsenic-contaminated water. This technology stands to offer new protection for people who are unable to get service from large municipal drinking water facilities, including those drinking well water or travelers in at-risk regions throughout the world.

Arsenic introduced into water through the dissolu-

tion of rocks, minerals and ores and from industrial effluents is highly toxic. Ingested orally at high levels, it is immediately lethal; long-term exposure to lower levels through drinking water causes cancer and skin lesions.

The 1993 edition of the World Health Organization's International Standards for Drinking-Water established 0.01 mg/L as the allowable concentration for arsenic in drinking water. Yet there are locations where concentrations well above this value have been detected; these areas include Argentina, Australia, Bangladesh, Chile, China, Hungary, India, Mexico, Peru, Thailand and the United States.

Surface water typically contains arsenate, the oxidized form of arsenic. Arsenate can be removed by reverse osmosis, which effectively filters water, or with a commercially available granular adsorbent material that captures the arsenic using an iron oxide or alumina surface.

In contrast, the arsenic found in well water and in arid climates is typically arsenite.

Until now, arsenite has been far more challenging. Treating water with chlorine oxidizes arsenite to arsenate, and readily removable arsenate is a byproduct of disinfection in large municipal drinking water treatment facilities. However, in smaller mobile reverse osmosis systems, residual chlorine will damage the water-purifying membranes.

The Molycorp research team worked with the U.S. Army Corps of Engineers to develop a one-step system based on Molycorp's patented application of cerium chemistry to treat arsenic-contaminated water.

Molycorp's answer to arsenic removal will come in the form of a portable filter or an end-of-tap device to trap arsenic as water flows through. The objective: to lower the concentration of arsenic from 1 part per million to below 10 parts per billion, thereby producing potable water.

This year, Molycorp expects to test a first-generation portable filter prototype and hopes to have a working prototype ready for high-volume applications.



X-ray fluorescence spectrophotometry is just one analytical tool Molycorp chemists use for material characterization. Adsorbent media, fused into the form of a glass disk, can be analyzed to quantify its elemental composition.

Driving Research

Advancing energy solutions down under

Just two years after forming the Western Australian Alliance for Advanced Energy Solutions, Chevron is making good on its commitment to develop Western Australia's rich offshore oil and gas resources.

In 2005, Chevron Australia Pty Ltd and Western Australian Energy Research Alliance signed an agreement to jointly participate in multiple petroleum industry projects in such areas as research, technology development, education and training. Since then, more than 20 unique projects have commenced, with several completed and more on the horizon.

Initial projects have centered on oil and gas exploration and development; hydrocarbon processing, industry-related health, safety and environment issues; and education and training initiatives. The development of new technologies—and application of existing ones—is expected to improve Chevron's business in areas relevant to its Australian interests, such as deepwater seismic acquisition and interpretation; the drilling and production of high-volume large bore wells; remote subsea production systems; and carbon dioxide capture and long-term containment.

"The alliance has made significant progress in a relatively short amount


of time, which clearly demonstrates Chevron's leadership in technology-driven research and development," says Anthony Eaton, who manages Chevron's participation in the alliance. "Australia is an important area for Chevron as it grows an integrated global gas business, and our participation in the alliance reflects a long-term commitment to developing world-class energy solutions in the country."

Chevron invested approximately \$2.5 million in the alliance in 2006 and expects to double that amount annually over the next two years. "Research costs rise as we develop existing projects to more advanced stages and identify new areas to explore," Eaton says.

The alliance doesn't just benefit the participants. "Chevron is on the leading edge in helping our industry develop the huge oil and gas fields offshore Western Australia," says Eaton. "We're driving research and technology developments that will help establish the area as an internationally recognized hub for advanced energy solutions. Our philosophy is to give back to the communities in which we operate and position Chevron as a partner of choice worldwide."

Bragging Rights

Chevron's talented inventors



Award-winning Chevron scientists Vesna Mirkovic and Spencer Wheat were acknowledged for their leadership of the team that designed the automated control system for Chevron's hydrogen energy stations and the importance of their invention in helping protect the environment.

Each year, the Houston Intellectual Property Law Association presents its Outstanding Inventors Award for distinguished technology innovations that have important practical implications. In 2006, two Chevron researchers received this award.

Chevron scientists Spencer Wheat and Vesna Mirkovic led the team that developed the purified-hydrogen generator (PHG). This self-contained fuel processing system converts pipeline-quality natural gas to high-purity hydrogen for storage and later use in fuel cells. Mirkovic and Wheat's research includes four separate

patents on various aspects of PHG technology and was conducted at the Chevron Technology Ventures facility in Houston.

Today, the system invented by Wheat, Mirkovic and their team is playing a vital role in Chevron's first hydrogen energy station, in Chino, California. The station, part of a five-year U.S. Department of Energy program being led by Chevron, is testing the feasibility of fueling automobiles with hydrogen. The Chino station uses proprietary Chevron technologies, including the PHG system, to transform natural gas into clean-to-use hydrogen under real-world conditions. It is one

of five stations that Chevron is building across the United States.

Mirkovic and Wheat credit Chevron for providing an environment in which inventiveness can flourish. "It's very motivating and inspiring to work for a company that knows how to look at the future in skillful ways and is committed to investing in it," says Mirkovic.

"There are certain jobs you have a passion for," Wheat adds. "Here, we get to work across the breadth of the company's operations. It gives you the freedom to learn, to see the big picture and bring new ideas to life."

The Innovation Incubator

Solar power generating steam for enhanced oil recovery. A new subsea pipe dramatically reducing platform weight. A high-performance computing system delivering a clearer, sharper look into reservoirs.

What do all of these projects have in common?

Each was brought into Chevron by Chevron Technology Ventures, whose role as Chevron's venture capital arm is to continually monitor new energy developments and move quickly to capitalize on commercial breakthroughs within the world's laboratories and early-stage companies. The unit then works with the external technology developer to create a product or service best suited for Chevron's needs and facilitates its adoption by other business units.

"Corporate venture capital is a valuable tool, allowing the company to inexpensively access a large pool of external technology developments important to our businesses," explains Jim Gable, manager of the venture capital unit. "In 2006

alone, Chevron business units piloted or deployed technologies sourced from 12 venture investments."

As a key entry point for new technologies, Chevron is involved with advanced energy technologies such as biofuels and other renewables. However, its larger focus is on early-stage companies and pioneering new developments in Chevron's core oil and gas business. The following three investments are among those showing exceptional promise.

DeepFlex Inc. is developing and commercializing DeepFlex™ flexible composite pipe. This nonmetal pipe is significantly lighter than conventional flexible pipe, with superior strength and resistance to corrosion and fatigue for deepwater and ultradeep-water oil and gas projects. The company produces pipe with an internal diameter of 2 inches to 8 inches (5.1 cm to 20.3 cm) and working pressures of up to 15,000 pounds per square inch. This combination of properties makes it ideal for deployment in water depths as great as 10,000 feet (3 km).

Chevron first used the piping on its Petronius Platform, where approximately 10,000 barrels of water a day are now being injected into the reservoir through the pipe. DeepFlex is building a manufacturing facility that can supply pipe directly onto deep-water installation vessels.


DynaPump Inc. manufactures an innovative surface-mounted rod pumping system that optimizes oil and gas production while improving energy efficiency and creating a smaller environmental footprint than traditional beam pumps.

Using this system, Chevron documented production increases from 5 percent to 20 percent and reductions in energy consumption of 20 percent or more over conventional beam pumps. Given the large number of pumps running nonstop throughout Chevron's worldwide operations, this represents significant potential savings. The operators and engineers at Chevron also worked with DynaPump to develop an ultralight-weight, low-maintenance unit.

Sub-One Technology Inc.

is pioneering a process capable of rapidly depositing diamondlike coatings on the internal surfaces of metallic parts, such as tubulars, chokes and nozzles. Sub-One uses diamondoids from Chevron's MolecularDiamond Technologies business. Diamondoids are small-scale diamond particles, measuring less than one-billionth of one-billionth of a carat. They are extremely hard and corrosion-resistant and reduce friction. Chevron scientists were the first to characterize several types of diamondoids and extract them in significant quantities from hydrocarbons.

Sub-One's coatings can be used in a number of mission-critical industrial applications. Potential uses include protecting production equipment from erosive flow streams, such as sand, and from corrosive environments, such as saltwater and chemicals. Additionally, the coatings can facilitate the safe handling of corrosive, high-temperature, high-pressure materials in refineries and chemical plants.



O rasan zor. By any measure, the Kazakh phrase for “unusually large” fits Tengizchevroil’s (TCO’s) supergiant Tengiz Field in Kazakhstan. Tengiz is the world’s deepest elephant field. Most oil fields measure their pay zones in feet; the Tengiz zone bulges nearly a mile (1.6 km) thick. With a surface area more than four times that of Paris, France, Tengiz currently ranks as the largest single-trap producing reservoir in existence.

As impressive as its physical size is the field’s economic scale. At one time, TCO was the planet’s biggest rail transporter of crude. Its year-after-year production increases made the Chevron-led joint venture a major player in the global energy industry. Today, Tengiz’s

yearly output could satisfy the annual oil demand of entire nations—Sweden, Pakistan, Chile and the Philippines, to name a few.

The destinies of both company and country are tied to the field, located on a remote, starkly beautiful plain within eyeshot of the Caspian Sea. For Kazakhstan, TCO generates hundreds of billions of tenges in economic activity, plus social investments in health, education, small business development and human capacity building. For Chevron, Tengiz represents a significant portion of the firm’s proved oil reserves.

Despite such riches, access to the full Tengiz treasure has for years been barred by two natural padlocks.



MANAGING EXTREME SIZES
UNDER EXTREME CONDITIONS

Unlocking the Tengiz Treasure

SGI/SGP safety specialist Akhlina Sakhipova surveys the project area. She says her biggest challenges are making sure workers correctly identify hazards and then implement steps to prevent incidents. Sakhipova also educates new employees and contractors on safety rules. "I want them to understand the rules are for their own benefit," she says, "not just something someone else tells them to do."

Tengizchevroil partners include Chevron, ExxonMobil, KazMunaiGas and LukArco, with stakes of 50, 25, 20 and 5 percent, respectively.

Center for Change



Tengiz's Sour Gas Injection/ Second Generation Project (SGI/SGP) holds the potential to transform the way oil is produced in Kazakhstan. However, as Guy Hollingsworth, managing director for Chevron's Eurasia operations, points out, much more than oil production has been transformed. The project's workers have changed too, and in ways that could profoundly affect their country and themselves.

"The success of SGI/SGP holds tremendous significance for the workers of Kazakhstan," Hollingsworth says. "Their growth in job skills and experience will benefit the nation for years to come."

A critical catalyst for this evolving workforce: the TCO-sponsored Craft Training Center launched in 2003. The center's purpose was to beef up the skills and professionalism of local construction workers such that they—and SGI/SGP—could meet universal standards for safety, efficiency and quality.

The first and largest facility of its kind in the country, the center has so far trained more than 4,500 Kazakhstan citizens in 14 construction disciplines, including carpentry, concrete finishing, masonry, pipe fitting, boiler making, welding, scaffolding, electrical work and instrumentation. Initially

restricted to SGI/SGP employees and contractors, the center now admits residents recommended by local employment officials.

Since privatized (and now known as the Caspian Technical Resources Center), the facility was specifically designed to meet the needs of both younger workers with little or no previous experience and seasoned pros who need to polish existing skills or get specialized training.

"Maximizing local and national employment and development has been a project priority," says Makset Taubaev, TCO's deputy general director. "Kazakhstan citizens make up more than three-quarters

of TCO's workforce, and the skills and technology they've learned are being transferred at a rapid pace, creating new opportunities."

In addition to the center, SGI/SGP routinely provides on-the-job safety instruction and skills training. Nearly 100 Kazakhstan engineers were sent to Camberley, south of London, for training in Western computer design; the group returned to Atyrau and handled about one-fifth of SGI/SGP's engineering. In 2005, managers and professionals from Chevron's other big projects spent a brain-picking week at SGI/SGP, sharing ideas and best practices.

The first is hydrogen sulfide (H_2S), a deadly gas. The second: reservoir pressures extreme enough to send 5-ton wellheads popping like champagne corks.

Hydrogen sulfide kills and corrodes. Detectable by the nose in small amounts, H_2S —or sour gas—at higher levels paralyzes the sense of smell. " H_2S is democratic and unforgiving," says Mike Koch, a Tengiz veteran who now heads international exploration for Chevron. "It doesn't care who you are, it will kill you instantly."

Although many petroleum reservoirs contain trace amounts of H_2S , the concentrations at Tengiz register upward of 17 percent. Similarly, whereas internal pressures at most oil fields cluster well under 1,000 psi

(pounds per square inch), pressures at Tengiz can be 10 times that high.

Indeed, due to such pressure, H_2S exists within the reservoir as a miscible fluid and dissolved gas, fully entrained with its oil. During processing, pressures are reduced, and sweet and sour gases are separated from the crude. The sour gas is then converted to elemental sulfur, stored and exported.

As early as 1994, Chevron engineers and scientists dreamed of reinjecting H_2S at Tengiz. The technology was straightforward enough, and Chevron had handled high-pressure/high- H_2S injection projects in the United States for years.



Far left: Trainees Zulhashev Meiram, Turgaliev Renat, Sundetov Bakyt and Galimullin Turarbek, at the TCO-sponsored Caspian Technical Resources Center in Atyrau, received instruction in industrial painting. The center is the largest facility of its kind in Kazakhstan and thus far has provided more than 4,500 Kazakhstan citizens with training in a range of construction disciplines for work in various industries.

Above: Heavy snows sideline earth movers, such as these, at Tengiz's Second Generation Project (SGP) site. When this photo was taken, the temperature had reached -40 degrees Fahrenheit (-40 C) on the ground and was a wind-driven -72 degrees (-60 C) atop SGP's tower.

Even so, the scale of the Tengiz challenge was forbidding. "We knew that reinjection was the key to tapping the field's potential," recalls Jim Blackwell, the field's environmental and safety manager in the early 1990s. "But in those days, 10,000-psi injector compressors were way beyond what anybody could realistically do."

Metallurgy posed another hurdle. With moisture, H₂S causes steel to crack, particularly at welds. To handle Tengiz's high pressures and gas volumes, the pipe needed to be as thick as gun barrels on a battleship. Because such pipes had never been used for sour gas, TCO launched an aggressive research effort.

"We didn't want any nasty surprises," says Sam Mishael, a senior research specialist. "We found that very thick pipe was more brittle than expected and difficult to weld. Knowing that before we started was crucial to the project's safety and our ultimate success."

By 2000, advances in compression technology and metallurgy had progressed enough to encourage TCO to form a Sour Gas Injection (SGI) study team. Meanwhile, a separate team was working to expand conventional production through the Second Generation Project (SGP), which would create the world's largest single-train sour crude processing facility. SGP would add about 12 million tons a year—or about 250,000 barrels a day—to TCO's output.

"The two teams got together," recalls Bharat Gael, TCO's general manager for capital projects. "They decided, for a relatively small increase in initial costs, we could combine SGI and SGP."

Under the plan, Tengiz's energy flow would in effect become a closed loop. "We'd strip off the sour gas from the oil," says Gael. "At SGI, we'd compress the gas to such high pressures that it would become instantly



Some 60 feet tall (18 m) and weighing more than 100 tons, a condensate stripper is lifted into position at the Second Generation Project's (SGP) crude processing area at Kazakhstan's Tengiz Field. When fully operational, the facility will be the world's largest single-train crude processing unit. Together with the Sour Gas Injection project, SGP will add about 250,000 barrels a day to the field's production.

miscible with the reservoir fluids. Then we'd pump it back into the reservoir."

About a third of SGI/SGP crude would be treated to allow sour gas injection back into the field; the rest would be processed normally to produce fuel gas, propane, butane and elemental sulfur. If injection didn't work, a fallback plan would expand gas and sulfur facilities at SGP.

In 2003, TCO ordered construction of the highest-pressure sour gas compressor ever built. Gas streams containing the highest H₂S levels are preferentially directed toward the compressor, explains site manager Dave Connell; the other streams are diverted to conventional gas processing and sulfur recovery.

Below ground, the injected H₂S maintains reservoir pressure and acts as a solvent, sweeping crude oil toward producing wells. "It's like dry cleaning the oil off the reservoir rocks where the injected fluid makes contact," Gael says.

SGI/SGP's \$6 billion-plus price tag lofts it well into the upper echelon of Chevron's megaprojects. It also spawned other innovations. More than 400 miles (644 km) of train track were rebuilt and upgraded to deliver project equipment. Towering sulfur recovery vessels and 130-foot-long (40-m) propane bullets were hauled to site on specially designed 64-wheel railcars riding on out-of-gauge rails. Computer simulations helped set train speed and position cargo to keep it from toppling inward or outward on curves. Still, some 30-foot-wide (9.1-m) loads teetered over the 5-foot-wide (1.5-m) tracks. Recalled one worker, "It was like trying to carry an elephant on a bicycle."

Human energy matched SGI/SGP's supersized gear. At its peak, more than 10,000 workers swarmed over the project, often for months at a time. By completion, total work hours are expected to exceed 130 million, nearly six times more than it took to build the Panama Canal. Despite the influx, project workers have tried hard to stay out of harm's way; they've logged several 15 million-hour stretches without losing a single workday to injury.

Because no one had ever operated compressors at such high pressures and H₂S levels, before beginning full-scale injection TCO embarked on a painstaking, sweet-gas-only test period. Full-scale sour gas injection is expected later this year.

Long before then, however, the massive project will have left its mark on Kazakhstan. SGI/SGP has seen more than \$1.2 billion in spending on local goods and services. More than 4,500 Kazakhstan citizens have

The Sour Gas Injection's "slug catcher" is the first checkpoint for dry injection gas coming from the Second Generation Project. The slug catcher removes any remaining liquid before the gas travels to the compressor.



gone through TCO's since-privatized Atyrau training center, providing a larger, better-prepared workforce for the nation's future projects. Designed for both seasoned and inexperienced workers, the center offers certification in 14 construction trades. "Those who've been trained here get snapped up," says Connell (see accompanying article on page 10).

"SGI/SGP has created thousands of careers for the country's workforce," says Makset Taubaev, TCO's deputy director. "Designers, engineers, managers and construction workers can look forward to new futures because of this project."

SGI/SGP lifts TCO's prospects too. Besides reducing sulfur output, "it nearly doubles the size of TCO's already huge oil business," says Gael. Despite this impact, the facility will be more energy efficient, emit half the greenhouse gases and sharply lower nitrous oxides compared with predecessor processing units. And by helping maintain reservoir pressures, injection lengthens the life of the field itself.

Clearly, the huge undertaking also adds to Chevron's luster. "Our industry," says TCO general director Todd Levy, "is being called upon to build ever-more-challenging plants in remote locations. SGI/SGP provides us with the opportunity to demonstrate that we are capable of executing these very large and technically complex projects."

Surely nothing—not even Tengiz itself—could better fit the meaning of orasan zor.

GOING TO EXTREME

Next time you're flying at 30,000 feet (9.1 km)—the typical cruising altitude of a plane—look out your window to the ground below. Imagine aiming a 6-mile-long (9.7-km) drill bit at a target the size of a big dining table. Imagine that drill bit penetrating waters cold enough to chill ice cream, rocks hot enough to grill chicken and pressures crushing enough to ruin the whole meal. Then imagine doing it all in pitch darkness, at \$100 million a pop.

That's how Chevron drills deepwater wells.

"Not so long ago, conventional wisdom said oil reservoirs couldn't exist in deep water," says Bobby Ryan, Chevron's vice president of Global Exploration and author of the oft-quoted airplane metaphor. "Well, some of our best reservoirs are not only in deep water, they're in ultradeep water. And our work is just in its infancy."

Case in point: Chevron's 2006 well test of the Jack discovery in the U.S. Gulf of Mexico's ultradeep water—defined as depths greater than 5,000 feet (1.5 km)—pushes "the boundaries of known technology," says energy-consulting company Wood

Mackenzie. "It opens up a whole new frontier," echoes oil field services giant Halliburton.

That frontier is the Lower Tertiary, a vast bed of rocks that are generally older, deeper and tighter than any other producing reservoirs in the Gulf of Mexico. The industry has about a dozen undeveloped oil discoveries in the Lower Tertiary, including six of Chevron's. But fears that the rocks were too compacted to allow a commercial flow of oil discouraged companies from drilling high-cost wells to gauge production potential.

The industry was stymied, but not Chevron. Its 5-mile-deep (8-km) well test at Jack became the deepest in the gulf's history, setting more than a half-dozen records for pressure, depth and duration in ultradeep water. The test produced 6,000 barrels of oil a day, a maximum rate to prevent equipment damage. The achievement opened the door for development of the Lower Tertiary.

"It's a textbook application of how technology drove opportunity," notes Barney Issen, a geophysicist with Chevron Energy Technology Co. (ETC).



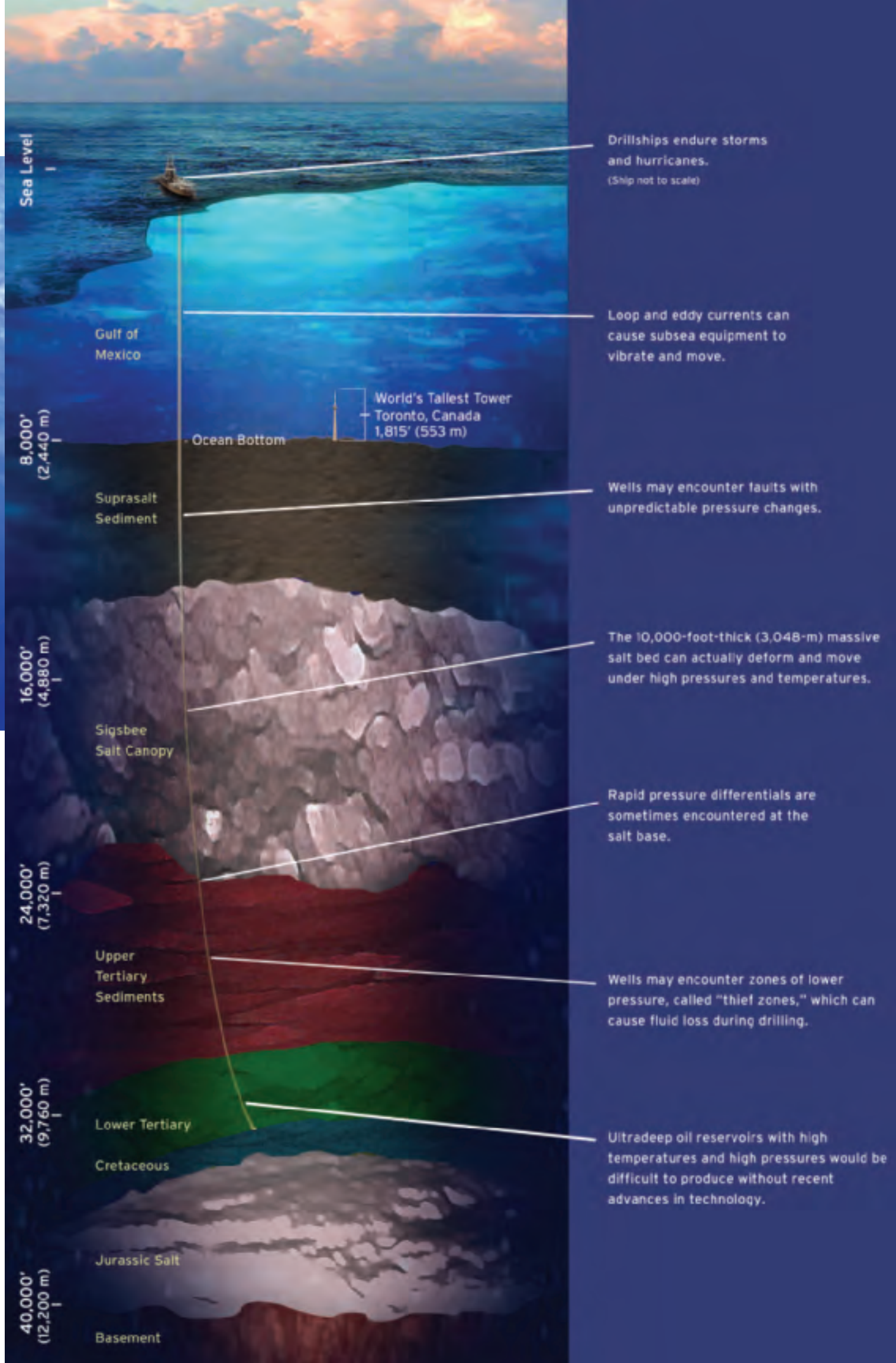
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CHEVRON EXPLORERS HANDLE THE PRESSURE

PHOTO: GREG SMITH

With Transocean's *Discoverer Deep Seas*, Chevron set deepwater records in the U.S. Gulf of Mexico. Now, two second-generation drillships being built are under contract with Chevron. The *Discoverer Clear Leader* and *Discoverer Inspiration* will be among the few drillships capable of drilling wells in more than 12,000 feet (3.7 km) of water and more than 28,000 feet (8.5 km) below sea level. Despite being nearly 300 yards long (274 m), these drillships will nonetheless be among the most maneuverable vessels in the world.

Challenges of deepwater exploration range from fierce hurricanes and loop currents to massive salt canopies and difficult geology.



Tails of the Deep



Filmed at 7,700 feet (2.3 km) in the Orphan Basin, the octopod *Benthoctopus johnsoniana* is widespread in deep waters. The one at left measures 2 feet long (0.6 m). Chevron uses ROV technology on the seafloor near its platforms to gather data and images for the scientific community.

Just because it's dark as coal, cold as slush and deep as, well, the North Atlantic doesn't mean it's lifeless. While that's not news to inhabitants, it has opened eyes among scientists watching the assortment of creatures who cruise past Chevron's remotely operated

vehicle (ROV) on the Orphan Basin seafloor.

Canada's Orphan Basin, nearly 250 miles (402 km) northeast of St. John's, Newfoundland and Labrador, is one of the world's last unexplored petroleum frontiers. The ROV was there for two reasons.

First, it was supporting Chevron and partners' 24,000-foot (7,300-m) well, Great Barasway F-66, one of the deepest ever drilled in Canada.

Second, the ROV was collecting video footage, stills and sediment for an international scientific collaborative called SERPENT (Scientific and Environmental ROV Partnership Using Existing Industrial Technology), led by the U.K. National Oceanography Centre.

"This gave scientists around

the world a privileged view of incredible animals in their natural habitat, including potential new species," says Janne Kaariainen, a SERPENT project research scientist.

Chevron's footage includes more than 2,000 species, including two sightings of Richardson's rays—only 18 had been seen in the region before—and a three-beard rockling, never before seen beyond 5,000 feet (1,500 m).

Learn more about the project at www.serpentproject.com.

Although technical hurdles remain to tapping the Lower Tertiary, the strides have been enormous. Leaps in computing and in the efficiency of Chevron's algorithms that process seismic data have enabled Chevron to create vast visual images of the earth's subsurface "faster and cheaper than anyone in the industry," says Jeb Blackwell, exploration technology manager for ETC.

Advances in offshore technology include the \$650 million drillships being built by Transocean for Chevron: *Discoverer Clear Leader* and *Discoverer Inspiration*. The vessels will be among the few drillships capable of drilling wells nearly 40,000 feet (12.2 km) deep, in more than 12,000 feet (3.7 km) of water and more than 28,000 feet (8.5 km) below the seafloor.

While Chevron will continue searching for massive oil fields—the so-called elephants—"there are plenty of smaller accumulations in deep water that we also want to monetize," says Paul Hansen, deepwater technology manager for ETC.

To develop tomorrow's finds, Chevron is working on a range of emerging technologies. In the future,

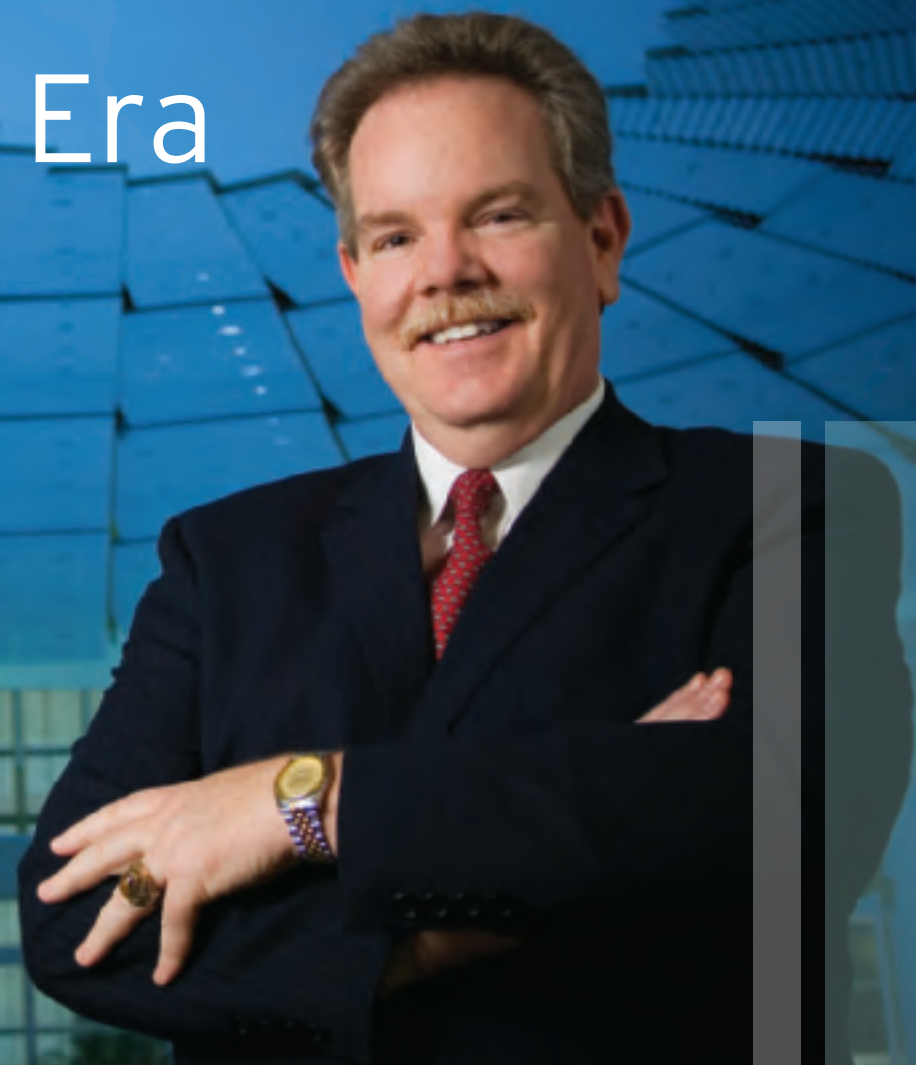
tiebacks as long as 200 miles (322 km) may connect smaller deepwater reservoirs to central processing hubs. Stand-alone platforms will still float in deep waters, though with smaller footprints. A new generation of separators—a standard and monolithic piece of platform equipment that separates produced fluids and gases—will be 85 percent smaller than current 100-foot (30-m) varieties. They will process faster too.

But the backbone of Chevron's deepwater developments will continue to be flow simulators, which predict how hydrocarbons will flow from the well bore, through the subsea and pipeline systems, up the riser, through separators, and into the export system. While industry has jointly created the next-generation flow simulators, Chevron has tailored them to plug into its proprietary modeling software, mitigating the chemical "nasties" in deepwater hydrocarbons that can clog, contaminate, freeze or otherwise shut down equipment.

Building these technologies speeds the pulse of veteran and freshly minted engineers alike. Says Hansen: "This is exciting. This is high tech. And this is our business."

Biofuels: A New Era

Q&A with Rick Zalesky



Next*: People hear a great deal about biofuels in the media today, but what exactly are biofuels?

Rick Zalesky: Biofuels are transportation fuels produced from biomass, which is living or recently living biological material. Biofuels are renewable, meaning that their sources can be regrown. Biofuels fall into two broad categories: first generation and second generation. First-generation biofuels include biodiesel made from soybeans, sunflowers and other refined vegetable oils, as well as ethanol made from corn and sugar cane. Second-generation biofuels are made from cellulose and waste products.

Next*: How is cellulosic ethanol different from first-generation ethanol?

Zalesky: First-generation ethanol is produced only from sugar-based plant matter such as corn kernels or sugar cane. The

remainder of the plant—the stalk and the leaves—is waste. In cellulosic production, however, a wide variety of plant matter—such as corn stalks, switch grass or forest waste—is converted into sugars, which are then converted into ethanol.

The benefit of cellulosic ethanol is that it opens the field to a variety of feedstocks and can help us avoid the food-versus-fuel debate. The challenge is in developing and implementing technologies that allow us to produce cellulosic ethanol on a scale that makes it commercially viable.

Next*: Chevron recently partnered with Weyerhaeuser to develop cellulosic biofuels. Why not just do it on its own?

Zalesky: Bringing biofuels to large-scale commercial production is a challenge that is too big for any one company or industry to tackle. Achieving it will require the combined efforts from the energy industry,

agribusiness, universities and research institutions, and governments. Chevron knows very little about growing crops, and that is why partnership is so important. We can't help the agricultural industry cultivate the crops, but we can work with it to determine what crops work best for producing fuel. We're working with these partners to identify, evaluate and develop ways to grow the biofuels industry. It is through this commitment to partnership—and by concentrating on end-to-end solutions that work on a large scale—that biofuels can become a viable source of energy (see articles on pages 32 and 36).

Next*: What role will biofuels play in meeting the world's demand for energy in the coming years?

Zalesky: Biofuels will be important in solving the world's growing energy demands, which are enormous—especially in China,

India and Latin America. The energy landscape is changing. There is increased competition for and investment in resources. The world is hungry to develop cleaner fuels. Biofuels offer an opportunity fossil fuels cannot. We can't design crude oil, but with biofuels we have the opportunity to create advantaged feedstocks that make better fuels, engineered through science and technology.

Next*: What is the mission of Chevron's new biofuels business unit?

Zalesky: This unit is working to develop production and distribution technologies at a scale that will make biofuels more economically viable. We're working closely with other Chevron organizations, such as Global Downstream and Supply & Trading, that have significant roles in the biofuels supply chain. This integrated approach provides us with a greater understanding of the benefits and issues and better equips us to develop large-scale biofuels operations. Short of growing the crops, Chevron is working to build capability along the entire value chain.

Next*: Why is it important for the company to diversify its fuel portfolio?

Zalesky: The demand for energy continues to rise. In the coming decades, we will need energy from all sources to meet this demand. Energy companies will provide whatever fuels customers demand, and it's up to us to explore all options and pursue those that appear most promising.

Biofuels are not a threat; they are part of the solution. But first, biofuels have to be sustainable both economically and environmentally. And second, we must be able to maintain our high standards for quality. If biofuels are to be viable, consumers will have to realize the same driving performance, cost efficiency and fuel economy that they do with current fuels, and the fuels will need to have improved environmental performance.

Next*: What has the new biofuels business unit accomplished to date?

Zalesky: The biofuels unit is researching, developing and applying new production and distribution technologies. So far, we've established research alliances with leading institutions such as the U.S. Department of Energy's National Renewable Energy Laboratory, the University of California at Davis, the Georgia Institute of Technology and Texas A&M University.

We want to broaden the choice of biofuel feedstocks and improve production processes. We are focusing, in particular, on accelerating the development of cellulosic transportation fuels, including ethanol. What is really exciting is that with thermochemical conversion technology such as gasification followed by the Fischer-Tropsch process, we can potentially create a molecule from biomass that is virtually identical to those making up gasoline and diesel today. This would simplify the distribution and transportation of

biofuels by integrating them into existing petroleum pipelines used to transport fuel products throughout the world.

We're also working with General Motors and the state of California in a demonstration project of E85—that's a fuel with 85 percent ethanol and 15 percent gasoline—to evaluate the commercial viability of the blend.

Next*: How are biofuels and other new energy sources reshaping our company—and the overall industry?

Zalesky: Biofuels are only one piece of the puzzle. We have more than a century of experience and data that indicate fossil fuels are the most efficient and economic energy sources. As such, they will continue to supply the majority of the world's energy needs. But as the population increases, economies prosper and more people become accustomed to comfortable lifestyles, we need to widen our energy portfolios. We want to continue to provide our customers with secure, efficient, affordable energy.

Next*: What excites you most about working on biofuels?

Zalesky: We're at the beginning of this industry—the dawn of the Biofuels Age. How often do you get a chance to be a part of that? It's a once-in-a-lifetime opportunity.

Rick Zalesky graduated from the Georgia Institute of Technology with a bachelor's degree in civil engineering. He began working for Chevron in 1978 as a design engineer at the Richmond, California, refinery and became the refinery's general manager 1999. In 2003, he was appointed the vice president of Chevron's biofuels and hydrogen business.



THE NEXT TRIL

UNCONVENTIONAL ENERGY TECHNOLOGIES AIM

Indigenous sagebrush now thrives and supports wildlife habitat and rangelands near Chevron's Kemmerer Mine, where high-quality Wyoming coal was produced 25 to 40 years ago. The reclamation process required replacing topsoil, restoring the land to natural contours and reseeding with native flora, says Steve Rex (above), the mine's safety and training manager.

In laboratories, board rooms and government offices, they're known as "the unconventional," a complex bundle of fossil-fuel resources and costly technologies fraught with big challenges and ripe with potential.

Experts describe the outlook for these resources—oil shale, liquid coal, heavy oil, synthetic diesel from natural gas, and others—in terms of hundreds of billions of barrels lasting well into the 22nd century. Despite a history of booms, busts, starts and stops, the unconventional seem poised for dramatic growth.

"Humankind used up its first trillion barrels of oil in 100 years," says Don Paul, Chevron's chief technology officer. "With rising energy demand, economic growth and expanding populations, the next trillion will be consumed in about 30 years."

"It's clear that the world will need to develop every kind of energy going forward. Unconventional technologies will deliver a significant new share of our future core energy supply, and Chevron is working on literally all of them."

Imagining the Unconventionals

What might this future look like? Picture major new plants near coal fields in China and the U.S. state of Montana synthesizing thousands of tons of coal into

millions of new gallons of motor fuels. Or a million barrels a day of oil from oil shale churned out from new installations in Brazil and the U.S. state of Colorado to make alternative jet fuels and diesels.

Imagine systems to capture the carbon dioxide produced from all these new facilities and, rather than releasing it into the atmosphere, injecting it into the earth for permanent sequestration—a technology that Chevron has already slated for use in Australia and is testing with partners elsewhere.

Finally, add lots of new facilities to make millions of tons of hydrogen from natural gas—not for cars, as envisioned in a different branch of the energy debate, but to help transform the raw, carbon-heavy unconventional into environmentally friendly fuels, says Paul.

Arguably, the Unconventionals Era has already begun, with Chevron and other companies operating huge new upgraders to make millions of barrels of synthetic crude oil from vast deposits of extra-heavy oil and sticky bitumen mined in Canada and Venezuela.

The company has also partnered with Sasol to advance gas-to-liquids projects worldwide, using the combined technological capabilities of both companies. In progress is a 34,000-barrel-per-day gas-to-liquids project in Nigeria, one of the world's first.

LION BARRELS

TO DELIVER FUTURE SUPPLY



Left: Huge reserves of raw coal from multiple U.S. locations, such as Chevron subsidiary P&M Coal's North River Mine in Alabama, could be converted into clean-burning liquid fuels using technologies now in research and development at Chevron laboratories.


Like coal, gas itself isn't considered unconventional, but converting these abundant resources—as well as the heavy oils and oil shale—into clean, liquid transportation fuels certainly is.

Heavy Oil Head Start

The company is already ahead of the game in heavy oil. Beyond its recent Canada and Venezuela ventures, Chevron is a world leader in elaborate steam injection projects producing hundreds of thousands of barrels a day in Indonesia and the United States, and it is now piloting this technology in a giant Middle East reservoir (see article on page 28). The challenge: make thermal-enhanced recovery, which is successfully under development with stable sandstone, work with

temperamental carbonate rock. Kevin Kimber, who heads Chevron's heavy oil research effort, says the company also recently invented a process to fracture and heat tight formations with high-pressure steam to capture oil from diatomite zones long believed impossible to tap.

Meanwhile, the company is researching new options for steam flooding using horizontal injection and production wells to tap a new Canadian tract holding more than 7 billion barrels of heavy oil. Among the next frontiers is thermal stimulation of deep heavy oil reservoirs now out of reach, says Kimber: "The deeper you go with heat, the more you lose it. We don't have all the answers to these problems today, but I'm confident we'll solve them. After several decades in heavy oil, we've gotten awfully good at it."



Chevron CEO Dave O'Reilly (left) discusses options for producing oil from unconventional sources with Tom Wairegi of Chevron Energy Technology Co. at the company's annual Technology Showcase, where top Chevron scientists and engineers share new ideas and success stories with employees and senior management.

A specialized hauling vehicle rumbles across the New Mexico landscape carrying a load of coal from a mine operated by Chevron subsidiary P&M Coal. Chevron is working on a coal liquefaction technology for making clean-burning synthetic diesel fuel to help meet global demand for motor fuels.

Oil From Shale, Liquids From Coal

Meanwhile in Colorado, the company has secured a federal oil shale tract to test *in situ* production technologies being developed with the U.S. Los Alamos National Laboratory. Oil shale is solid rock—oil can't just be pumped out. But this is a problem well worth solving: the government estimates that western U.S. shale beds hold some 800 billion recoverable barrels—a 110-year U.S. oil supply at current consumption levels (see accompanying article on page 24).

Chevron envisions creating underground chambers of rubble, then using chemistry to convert the oil shale. This should cost less than heating the shale and would save energy and limit landscape disturbance and carbon dioxide emissions. Some 75 people are involved part

time in the work, says Chevron's oil shale technology manager Robert Lestz, who calls the initiative a model of Chevron's integrated approach to developing technology and projects for the unconventional.

For all the potential of heavy oil and oil shale, coal to liquids could be even bigger, especially in the United States, sometimes called the "Saudi Arabia of coal." Here again, Chevron has an edge, with its subsidiary The Pittsburg & Midway Coal Mining Co. (P&M Coal), operating major western U.S. mines and providing high-quality samples for the company's research.

But while liquefaction technology is mature and proven (Sasol has produced coal diesel in South Africa for decades), Chevron is exploring a different approach and plans to test it with a new pilot project in 2008.

Liberating Oil From Shale

Within the United States lies an enormous energy bounty—an estimated 2 trillion barrels of hydrocarbon resource trapped in oil shale. That's as much conventional oil as the world is expected to ultimately produce. And it could conceivably meet all of the United States' energy needs for 110 years at current consumption levels.

Realizing the potential value in these vast reserves, primarily in the U.S. states of Colorado, Wyoming and Utah, will not be easy. Previous attempts in the 1980s were too expensive and too energy intensive to compete with conventional oil resources. They also required extensive mining and needed large quantities of groundwater in an area that is already among the driest in the country.

Unconventional Solutions

Chevron recently earned oil shale lease rights for a research and development project in Colorado's Piceance Creek Basin. To help meet the challenge, the company formed a research alliance with the Los Alamos National Laboratory in September 2006. The lab, located in Los Alamos, New Mexico, is one of the largest multidisciplinary scientific institutions in the world, with world-class talent and technology and substantial facilities for research and development.

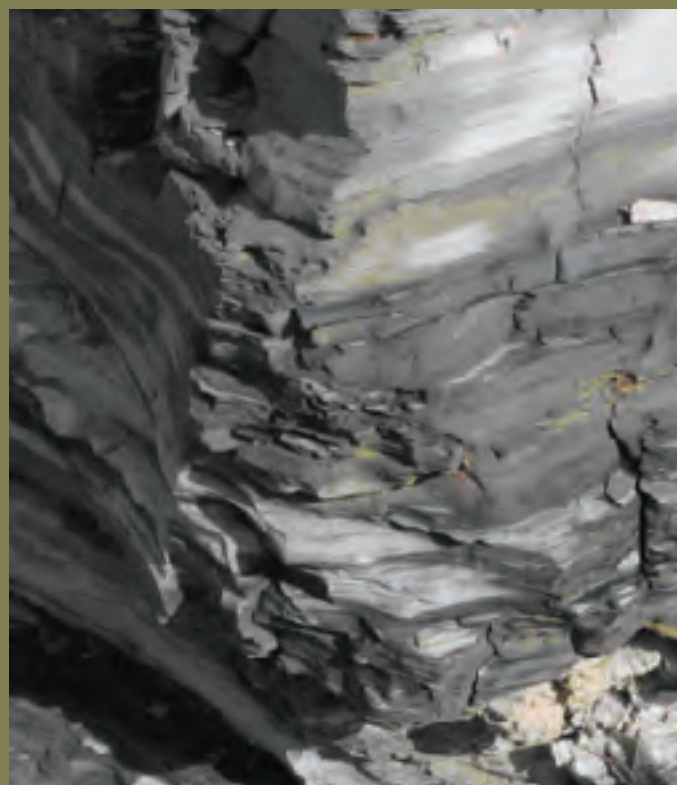
This early-stage research project is supported with

multimillion-dollar funding from Chevron and will establish the fundamental science and engineering needed to develop an environmentally responsible and commercial method for recovering oil and gas from western U.S. shale. As part of its role, Los Alamos will be involved in reservoir stimulation and modeling and experimental validation of new recovery technology, including *in situ* recovery methods.

"By tapping into a science laboratory of this caliber with smart people in many subjects, you get some very creative thinkers to attack a problem in an unconventional way. Often, the solution can be surprisingly simple," explains Manny Gonzalez, Chevron senior engineering adviser and Los Alamos alliance manager.

Getting Down to the Molecular Level

Oil shales are sedimentary rocks containing a high proportion of organic matter called kerogen, which can be converted into crude oil or natural gas. "The Chevron-Los Alamos approach starts at the molecular level and focuses on a comprehensive understanding of kerogen's fundamental chemical structure," says Robert Lestz, Chevron's oil shale technology manager. "From there, we'll develop an engineered solution to unlock the kerogen from the inorganic rock and flow it or its product to the surface."



Environmental concerns will also be addressed. "Water usage issues are particularly important," says Urmas Kelmser, senior hydrologist for Chevron's oil shale project. "But because our approach focuses on *in situ* technology, our water need should be significantly lower than what was required using legacy mining methods. We're also working to protect groundwater in our lease area by carefully characterizing the formation so we know what areas to avoid."

Liberating the shale's potential is enormously complex, and it could take up to a decade for the project to become commercial. "When we process conventional oil in refineries, we're dealing with Mother Nature on our turf," says Phil

Rosen, a member of the oil shale team. "When we process oil shale *in situ*, we're on her turf."

Lestz likens the Chevron effort to the mission to place a man on the moon in the 1960s. "In addition to achieving this important milestone, the project created a scientific bonanza, leading to the development of new products and technologies, from Velcro® fasteners to cold lasers," he says. "The oil shale project could have similar value for Chevron, yielding an influx of new technologies that will benefit the company for years to come."

Far left: This outcropping of oil shale in western Colorado's Rio Blanco County in the United States is the same formation Chevron plans to produce. On the Chevron lease site, the rock is approximately 1,000 feet (305 m) below the surface. "When we process conventional oil in refineries, we're dealing with Mother Nature on our turf. When we process oil shale *in situ*, we're on her turf," says Phil Rosen, a member of Chevron's oil shale team.



The Sasol Chevron GTL Challenge in 2006 proved the long-range performance qualities of gas-to-liquids fuel, a low-emission synthetic diesel made from natural gas, through all kinds of road conditions across Africa and the Middle East, including the Malawi countryside, shown here. Chevron is working on a new GTL facility in Nigeria.

"We're looking at direct liquefaction, which we believe promises lower capital costs for facilities, higher energy yields and lower carbon dioxide emissions from the manufacturing process," says Don Mohr, who leads Chevron's coal-to-liquids research efforts.

"Sasol uses an indirect process that first gasifies the coal, then makes liquids from the gas. We plan to grind up the coal, mix it with a solvent, and then add a catalyst and hydrogen at high temperature and pressure. Coal is very carbon-rich, so you have to rebalance the molecular mix to get a better ratio of hydrogen atoms to carbon atoms in the finished products."

Manipulating Molecules

Mohr's molecular view reflects the 21st-century strategy behind Chevron's new Process, Analytical and Catalysis (PAC) group. This extended family of scientists and engineers was created in 2005 and is organized to drive a vision for managing unconventional oil from extraction through upgrading, processing, and fueling tanks of cars, trucks and planes.

"Humankind is going to need all the unconventional oil, so we need to create technologies for them all," says Paul Allinson, PAC's general manager at Chevron's Richmond Technology Center in California.

In addition to linking multiple technologies into integrated systems, PAC's "wells to wheels" strategy requires viewing the unconventional oil not merely as rocks, gases and crude liquids; it requires planning for their conversion into new streams of hydrocarbon molecules that serve existing market needs while creating the opportunity to formulate superior new products in the future. They're all convertible into future fuels through the well-advanced science of catalysis—the nanotechnology of the oil industry—where Chevron has deep roots and cutting-edge capability, says Allinson.

Allinson is especially excited about PAC's most promising new proprietary Chevron catalytic technology, which can convert a variety of carbon-laden streams—such as residual fuel oil and liquid coal—into high-quality transportation fuels without yielding low-value petroleum coke. He sees multiple applications across the spectrum of unconventional oil and believes it could help push the entire industry forward.

"With our capability to define hydrocarbons by their basic molecular structure, we can create precision processes to manipulate molecules and synthesize resources into fuels tailored to future engine technologies."

The Train That Must Not Falter

Oronite is the choice when reliability is the only option

The journey of the *Lhasa Express*, between Tibet's capital and Golmud, in China's northwestern province of Qinghai, is incomparable. The Tibetan Plateau, through which China's newest diesel-electric train passes, is known as the "rooftop of the world"—some of it permanently frozen land. Much of the course is at an altitude of about 13,000 feet (4 km), but at one point it reaches 16,630 feet—3 miles (5 km) above sea level. This "sky train" is the only one in the world to operate at such a high elevation.

The travelers can vouch for that. Even though extra oxygen is supplied to the passenger cars during most of the trip, some of the travelers avoid altitude sickness by also using the personal oxygen canisters onboard.

If that seems dramatic, take a deep breath before contemplating the action inside the three

4,400-horsepower diesel-electric locomotives at the helm of the train. This is where Chevron Oronite Co.'s technology is at work.

Except during the train's scheduled stops, the engine parts move continuously. The finished engine oil is what lubricates their metal surfaces and acts as a cooling medium—the engine oil sump temperature hovers around 180 degrees Fahrenheit (82 C). Combustion byproducts and other contaminants, entering the engine via the air intake, land in the engine oil and are dispersed by it. The performance additives—Oronite Lubricating Oil Additive (OLOA®) 167 and OLOA® 2000—keep the finished oil formula- tion from rapidly deteriorating due to the severe engine operating conditions.

OLOA 167 is a viscosity index improver, enabling the engine oil to adjust its thickness, depending on



conditions. OLOA 2000, a dispersant detergent additive package, keeps the contaminants in the engine oil from aggregating, forming a sludge or clogging engine parts. Tom Gallagher, Oronite's railroad technical liaison, explains, "OLOA 167 and OLOA 2000 are used in combination with select domestically available base oils to formulate finished oils that meet performance specifications and address the unique operating conditions."

Nonstop reliability is a must for a train traveling 48 hours through arduous, remote terrain. Water freezes at 32 F (0 C), and that would happen inside the engine if the locomotive broke down or were forced to idle at a standstill for a prolonged period

of time in freezing temperatures. The train engine is designed to dump its water if its temperature falls below 40 F (4 C) so mechanical damage won't occur. And there could be other chilling implications: oxygen supplies for passengers on the train are limited, and rescue time could be lengthy.

Technical collaborators Chevron, engine manufacturer General Electric, and China's Ministry of Railways and its Academy of Railway Sciences never lost sight of the formidable issues. Says Yu Bai Qiang, Chevron Oronite's technical sales manager in the company's Beijing office, "We are proud of our contribution and honored to have been part of such an extraordinary success."

The *Lhasa Express* passes the La Sa Te bridge near the railway station. The passenger train travels as high as 3 miles (5 km) above sea level on its remote route between Qinghai and Tibet. Oronite® additives help keep the engine running under the most severe operating conditions.



PNZ STEA

UNLOCKING UNTAPPED



This slurry evaporation system produces an ultrapure distillate ideally suited to turn into steam, which then is used to coax heavy oil out of the ground.

PHOTO: CHRIS MARTIN

M

OIL

FLOOD

Early results from Chevron's onshore steamflood test in the Partitioned Neutral Zone (PNZ) suggest that the region may be able to unlock its reservoirs of molasseslike heavy crude oil, adding billions of barrels to PNZ reserves. Chevron's pilot in the Wafra Field is one of the first steamfloods in the Middle East.

"We bring to the PNZ decades of experience in steamflooding," notes Kevin Kimber, manager of heavy oil for Chevron Energy Technology Co. Chevron began "steaming" more than 40 years ago in Kern River, California. Today, the company produces nearly 50 percent of the world's steamflooded oil, more than any other company.

In steamfloods, injected steam migrates through the reservoir, heating viscous heavy crude such as Wafra's Eocene-epoch oil, which averages 18 API gravity, into a syruplike consistency that can be pumped out.

Kern River is still producing, nine times as much today as when Chevron began steaming it in 1965. Chevron also exported its technology to Duri, Indonesia, the largest steamflood in the world.

Yet "steaming" the carbonate reservoirs of Wafra presents technical challenges compared with the sandstone reservoirs at Kern River and Duri.

With the notable exception of Kuwait's Burgan Field, the world's largest sandstone reservoir, virtually all the large reservoirs in the Middle East are carbonate. They were formed more than 50 million years ago when the Middle East was a shallow sea, home to corals and other marine organisms that grew, produced calcium carbonate or limestone, then died and accumulated.

Steam and high temperatures near the injector wells can dissolve some of carbonates' mineral components. The salts may precipitate elsewhere in the

reservoir, clogging rock pores that the oil would otherwise flow through. The salts also can "scale up" wells the way cholesterol blocks arteries. Chevron is evaluating whether precipitating salts are being generated at Wafra and, if necessary, what mitigating actions would be effective.

Chevron also is testing a water treatment system that removes high levels of dissolved minerals from Wafra's produced water (water brought up with oil during production then separated out), used to generate steam for continuous injection. Purifying the water is key: like precipitating carbonate salts, salts in the steam can scale up surface equipment and wells, resulting in unacceptable downtime. The water treatment system Chevron uses produces an ultrapure distillate that is ideally suited for making steam.

Another technology Chevron is testing condenses vapors that otherwise accumulate between the well bore and the casing, threatening to reduce the flow of oil from surrounding rocks into the well bore.

Using results from its small-scale test, Chevron designed a large-scale pilot to determine how to optimize full field development. "This large pilot could open up opportunities for economically developing other heavy oil reservoirs in the region," notes Ahmed Al-Omer, president of Saudi Arabian Chevron.

It could also open up job opportunities. Full field development of Wafra and other heavy oil developments, such as Canadian tar sands, will require people skilled in heavy oil and thermal operations. "Steamflooding is just as technically challenging as deep water," says Kimber. "It's technical, it's cutting-edge, and it's exciting."



To build and retain its top-notch workforce, Chevron offers development opportunities, university and technical training, expert mentoring, and international assignments. At the company's fourth annual Career Expo in San Ramon, California, in 2006, (from left) Carlos Enllanche and Keijiro Varela joined some 250 other employees from locations worldwide. Workshops and presentations focused on professional development and career opportunities across the breadth of Chevron's businesses.

Escalating global demand for energy has sparked aggressive competition among energy companies to recruit top-notch employees, particularly from among today's leading science and engineering graduates, whose future innovations will lead the industry tomorrow.

To expand our connections with the global workforce that will help fuel Chevron's future growth, we're expanding long-term partnerships with top universities around the world through our recently launched multidimensional University Partnership Program.

Chevron's initial partners will include 16 universities, from countries as diverse as Australia, India, Indonesia, Kazakhstan, Thailand, the United States and Venezuela. Each university has unique strengths and is considered, in one way or another, to be "best in class."

A senior Chevron executive will lead the program at each university. Working with top university officials to identify opportunities for strategic partnership on long-term initiatives will promote various aspects of education, research and recruiting.

We are building customized programs to optimize potential synergies between Chevron and each university. We know that financial contributions alone do not provide the best benefit to the universities or Chevron, so the program will also engage many Chevron employees in creating and sustaining the relationships. We'll integrate the program's efforts with a broad spectrum of existing Chevron networks and processes.

Among the many options we're exploring for the program are to:

- help universities create new degree programs and strengthen existing programs by providing Chevron lecturers, data and state-of-the-art equipment;
- provide scholarships, internships, graduate fellowships and faculty funding as appropriate;
- allow faculty sabbaticals at Chevron facilities, participation in internal Chevron forums, enrollment in Chevron courses, and field trips to enhance faculty and student appreciation and understanding of our industry;

- launch major new research programs addressing critical technical challenges;
- supplement our employees' educational opportunities, invite university faculty to serve as guest lecturers at Chevron events, provide employees with access to distance learning, and offer employees full- or part-time advanced degree opportunities.

We will consider a broad range of alternatives in creating a fit-for-purpose program for each university—a complete package that provides and promotes a career path for students while showcasing Chevron as a preferred employer and a great place to work. Working with Chevron's recruiting coordinators and career development committees, the University Partnership Program will help enhance the company's recruiting presence on these campuses. In fact, many of the systems that we build to support this increased effort might advance Chevron's recruiting at all universities.

Our vision for the University Partnership Program is that it will benefit all partners. It will help build Chevron's future global workforce by attracting top-notch graduates from around the world—offering them mentoring and career opportunities—and by providing our current employees with the best continuing education possible. Alliances with world-class institutions also will help Chevron maintain its technical leadership. Universities will benefit from funding, Chevron expertise and opportunities for real-world applications of emerging technologies.



From the World's Classrooms to World Class

Vantage Point with Eve Sprunt

Eve Sprunt is manager of Chevron's University Partnership Program and Recruitment. She is a 28-year veteran of the petroleum industry and recently served as president of the Society of Petroleum Engineers. She holds bachelor's and master's degrees in earth and planetary sciences from the Massachusetts Institute of Technology and a doctorate degree in geophysics from Stanford University.



From Trash to Treasure

Chevron partners to develop cellulosic biofuel technologies

Imagine agricultural and forest byproducts (known as cellulosic biomass), such as rice straw, switch grass and municipal solid waste, being developed into ethanol, renewable diesel and other biofuels. Chevron and its partners aren't just imagining a world where this is possible—they are working to make it a reality.

These second-generation biofuels, which use renewable sources of forest and agricultural waste, are viewed as an important advancement over first-generation biofuels made from such crops as corn, sugar cane and soybeans.

Rick Zalesky, vice president of Chevron's biofuels and hydrogen business, says, "Once developed, second-generation processing technology will allow waste products to be converted into renewable transportation fuels, opening the door to a new phase in alternative energy."

Chevron has teamed up with the University of California at Davis, the Georgia Institute of Technology, Texas A&M University, the U.S. Department of Energy (DOE), the Colorado Center for Biorefining and Biofuels, and Weyerhaeuser Co. to research and develop new process technologies to convert cellulosic biomass into biofuels and study the feasibility of large-scale production.

As part of its partnership with UC Davis, Chevron will support a broad range of the university's scientists and engineers with funding of up to \$25 million over five years. At Georgia Tech, the company will contribute up to \$12 million. Both collaborations call for research to develop commercially viable processes for producing transportation fuels.

Georgia Tech researchers plan to develop processes to directly convert

biomass into hydrogen and hydrocarbon transportation fuels. Researchers also will study the feasibility of producing commercial volumes of these fuels and the conditions needed for large-scale production facilities.

In the collaboration with UC Davis, along with supporting scientists and engineers, Chevron will help support the university's research and teaching programs on biofuels and help fund a demonstration facility to test the commercial readiness of these emerging technologies.

Chevron will also fund research that complements DOE-sponsored work at the National Renewable Energy Laboratory (NREL) on bio-oil reforming, a process by which bio-oils derived from the decomposition of biological feedstocks are then converted into hydrogen. This research may expedite the development of a



feedstock-flexible distributed reforming process for renewable hydrogen production and provide the hydrogen necessary in some potential biofuels conversion technologies.

The company recently joined the Colorado Center for Biorefining and Biofuels—a consortium of the University of Colorado at Boulder, Colorado State University, the Colorado School of Mines, NREL and other private companies—and will work with them on their mission to research new biofuels and biorefining technologies.

Chevron's partnership with the Texas A&M Agriculture and Engineering BioEnergy Alliance will support research to accelerate the production and conversion of crops for manufacturing ethanol and other biofuels from cellulose. Research will focus on several technology advancements, including assessing, cultivating and optimizing production of second-generation energy feedstocks

for cellulose and bio-oils, with a focus on nonfood crops; characterizing and optimizing the design of dedicated bioenergy crops through advances in genomic sciences and plant breeding; developing integrated logistics systems; and developing advanced biofuels processing technologies.

Chevron has signed a letter of intent with Weyerhaeuser to assess the feasibility of commercializing the production of biofuels from cellulose-based sources. Feedstock options include a wide range of materials from Weyerhaeuser's existing forest and mill system and cellulosic crops planted on Weyerhaeuser's managed forest plantations.

The partnership reflects the companies' shared view that cellulosic biofuels will fill an important role in diversifying the nation's energy sources by providing a source of low-carbon transportation fuel. The venture leverages the strengths of both companies, combining Chevron's

technology capabilities in molecular conversion, product engineering, advanced fuel manufacturing and fuels distribution with Weyerhaeuser's expertise in the collection and transformation of cellulose into engineered materials, innovative land stewardship, crop management, biomass conversion and capacity to deliver sustainable cellulose-based fiber at scale.

"Through these collaborations, we hope to broaden the energy mix by accelerating development of next-generation process technologies that will convert cellulosic biomass into biofuels," says Don Paul, Chevron's chief technology officer. "Process efficiency and suitability for industrial-scale deployment, similar to today's transportation infrastructure systems, are key success factors."

This new source of renewable energy holds tremendous possibility. Biofuels will be part of the world's more diverse energy future, and Chevron is helping lead the way.

First-generation biofuels are produced from sugar-based plant matter such as corn kernels, soybeans and sugar cane. In second-generation, or cellulosic, production, a wide variety of plant matter—such as corn stalks and leaves, switch grass and forest waste—is converted into sugars, which are then converted into ethanol. The benefit of cellulosic ethanol is that it opens the field to a variety of feedstocks and can help avoid the food-versus-fuel debate.



Unlike conventional solar voltaic panels that convert sunlight directly to electricity, the solar power tower (above) and the parabolic troughs (far right) being considered for San Joaquin Valley, California, operations would concentrate solar power using mirrors to harness the heat for conversion to steam.

Providing Secure Energy

Chevron Energy Solutions is partnering with Keenan Development to build and operate a \$100 million central utility plant to provide secure energy for the U.S. National Interagency Biodefense Campus under construction at Fort Detrick in Frederick, Maryland. The plant is the largest of many federal projects Chevron has developed to improve energy reliability and efficiency.

When completed in early 2008, the new energy-efficient facility will deliver highly reliable steam, chilled water and conditioned standby emergency power to the campus. The plant will also support some of the highest-level biosafety containment laboratories in the world.

"The energy produced by this plant will help ensure continued progress

in biomedical research and other critical work at Fort Detrick," says Colonel Gina Deutsch, garrison commander at the facility.

Chevron and Keenan Development were selected over several other teams of national energy services and development companies.

"Chevron is honored to help in the development of this facility," says Jim Davis, president of

Chevron Energy Solutions. "We recognize that energy reliability and efficiency are critical concerns of the U.S. government, and we're proud to provide the highest level of energy security possible."

Chevron partners with institutions and businesses to increase efficiency, reduce energy consumption and costs, and ensure reliable, high-quality energy for critical opera-

tions. Through contracts with the U.S. Department of Defense and the U.S. Department of Energy, for example, company-engineered and -installed facility improvements at three military bases will save U.S. taxpayers at least \$151 million. In California, Chevron's upgrades will save the U.S. Postal Service more than \$2 million a year in energy costs.

Piping Hot

Beyond electricity: creating steam from the sun



Harnessing the power of the sun is nothing new for Chevron. For more than a decade, Chevron has engineered the installation of solar panels atop colleges, post offices, and other community and municipal facilities as a means of improving energy efficiency and reducing energy costs.

In the San Joaquin Valley of California, the company uses solar technology to improve the efficiency and effectiveness of its core business there: oil production.

Chevron already uses the power of the sun to generate electricity to help power its business. In the desertlike Midway Sunset oil field just outside Bakersfield, California, an assemblage of 4,800 sloped, photovoltaic solar panels—arranged in 400 strings of 12 modules each—are clustered within a fenced border. This solar mine converts energy from sunlight into an average of 900,000 kilowatt hours of

electricity a year, which helps fuel the generators that power enhanced oil recovery efforts in the surrounding oil field.

But this time around, Chevron is turning to the sun not as a source of electrical energy but as a supplier of heat to produce steam. The operation currently uses natural gas to generate the massive amounts of steam injected into the reservoirs to make the heavy oil flow more easily. The demonstration project being considered for these fields would use new technology and equipment to capture the sun's heat to produce the steam. This technology would add value to these enhanced oil operations by providing lower-cost steam, reducing natural gas fuel consumption and lowering greenhouse gas emissions.

As the recipient of roughly 2,200 hours of good solar radiation a year, the

San Joaquin Valley is an ideal place to harness this energy. Two technologies being considered for the solar-to-steam heat conversion are parabolic trough collectors and solar towers.

"This is both a new concept and a new application of existing technology," explains Jerry Lomax, Chevron Technology Venture's vice president of emerging energy. "There's only one other solar steam project on the planet, and it supports a power plant," he adds. "We'd be the first to use the technology in an oil field."

Parabolic trough collector technology involves erecting parallel rows of 40-foot by 19-foot (12.2-m by 5.8-m) glass-mirrored troughs. The solar radiation collected by the troughs is concentrated onto absorber tubes filled with produced water (water brought up with oil during production, then separated out) to turn it into steam.

Solar tower technology uses an array of mirrors to concentrate the sun's rays onto an above-ground water tower, heating it and producing steam. With both technologies, the steam created by the sun's heat is then injected downhole for enhanced oil recovery.

Spread over 40 acres (0.16 sq km), the demonstration project would also include a water treatment plant as well as a steam distribution system. It would have the capacity to produce 115,000 pounds (52,163 kg) of steam per hour, offsetting approximately 2,400 hours per year of natural gas consumption and reducing carbon dioxide emissions by approximately 15,000 tons per year.

Waste Doesn't Go to Waste

Power from 'the digester'



Dick York, recently retired superintendent of the wastewater treatment plant in Millbrae, California, holds a flask of sludge in his right hand and effluent in his left. He says, "Chevron has been a valuable partner, working with us to pioneer a project that could shape the future of these plants around the country."

"The city of Millbrae approached us with a very complex situation, with the goal of upgrading its facilities with more effective technologies while keeping costs under control," says Jim Davis, president of Chevron Energy Solutions. "We love these types of challenges because they allow us to explore innovative solutions for energy production."

The unique system includes a grease receiving station, an expanded cogenerator and other upgrades that result in annual revenues and energy savings of \$366,000 for Millbrae and nearly double the amount of "green power" produced at the plant.

The grease and other organic matter produce enough biogas at the plant to generate about 1.7 million kilowatt hours annually, which meets 80 percent of the plant's power needs and reduces its electricity purchases. This lower demand for utility-generated power reduces carbon dioxide emissions by 1.2 million pounds annually, the same amount of carbon dioxide absorbed by planting about 170 acres of trees.

The process of making fuel from food waste is perfectly natural. In many respects, it's the biological and mechanical equivalent of the human digestive tract, using tanks, filters and pipes to perform the functions of the stomach, bladder and intestines.

Wastewater—the stuff of drainpipes and toilets—is typically treated at wastewater treatment plants using gravity and microorganisms. Microorganisms (bacteria) in the wastewater use the waste material as a food source and, in the course of "feeding," convert the waste to byproducts that include methane

gas, a useful energy source. But unless that gas is captured, it escapes into the atmosphere as a greenhouse gas and its potential as fuel is unrealized.

Chevron helped the city of Millbrae, California, make the most of its wastewater's energy potential. In late 2006, Chevron completed the installation of a first-of-its-kind facility that enables the wastewater treatment plant to use kitchen grease—the 3,000 gallons (11,400 liters) it receives daily from restaurants—to naturally produce additional biogas. The biogas is used to generate renewable power and heat to treat the city's wastewater.

Who is going to help power the world's mega-cities in 2015?

Join us, and you will.



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* Heavy Oil's Journey

A strong hydroprocessing heritage and proprietary technology are advantages for Chevron. As the world shifts to unconventional energy sources, Chevron's refining processes and molecular research position the company to meet the challenges of processing these new feedstocks. The Pembroke Refinery (above), in Wales, successfully processes heavy, highly acidic crude oil from the Doba fields in Chad. Pembroke is admired for its flexibility in adapting to these difficult crudes.

PHOTO: JOHN STURROCK



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