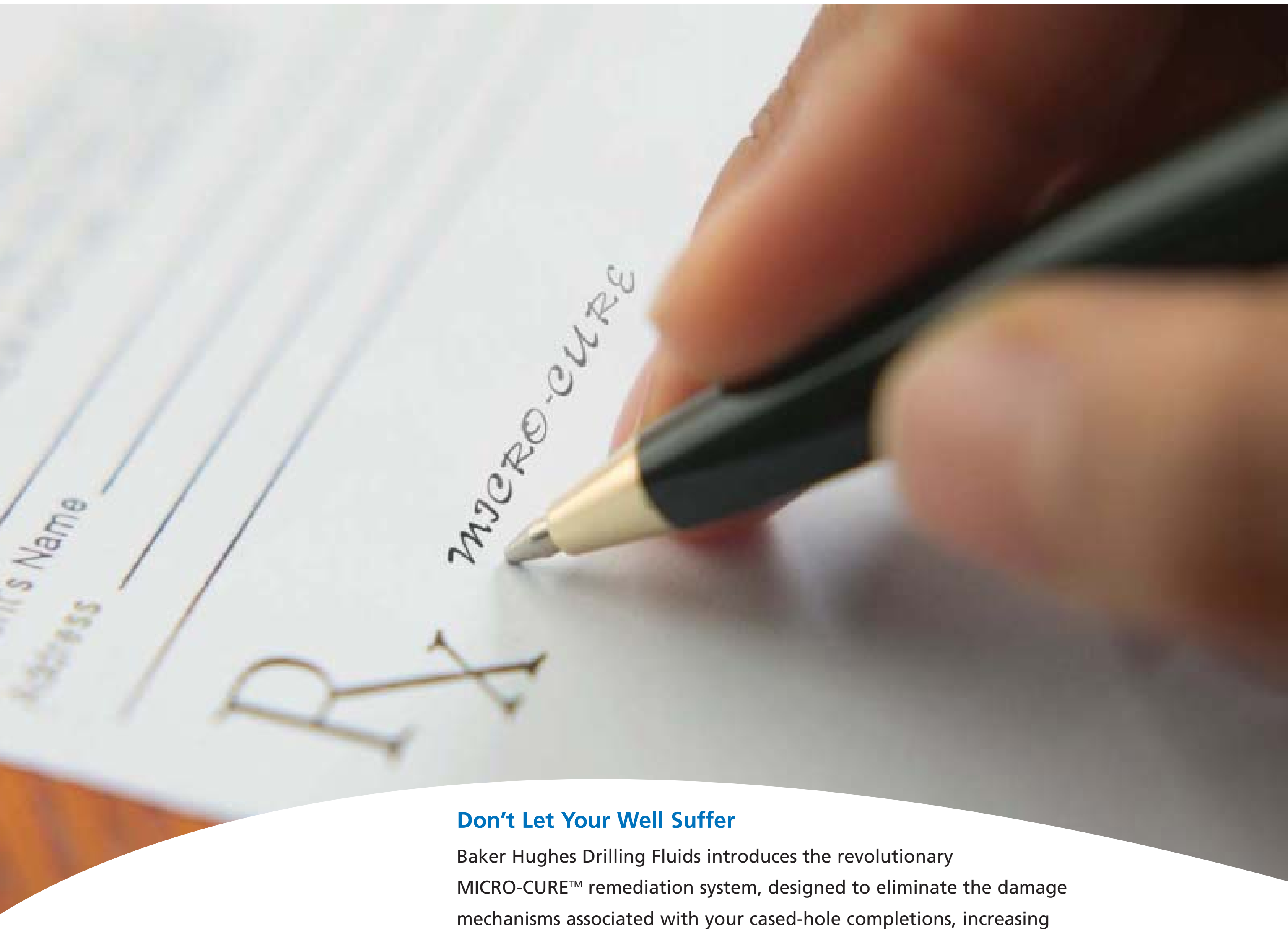
Sometimes a Prescription is Necessary



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Semi-annual construction updates are provided in the following areas:

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- Pipeline
- Gas Processing
- LNG
- Sulfur

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- Shipyard & Country
- Delivery Date
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Major upstream mega-projects throughout the world: location, project name, peak year, production volume, operator company, and development type.

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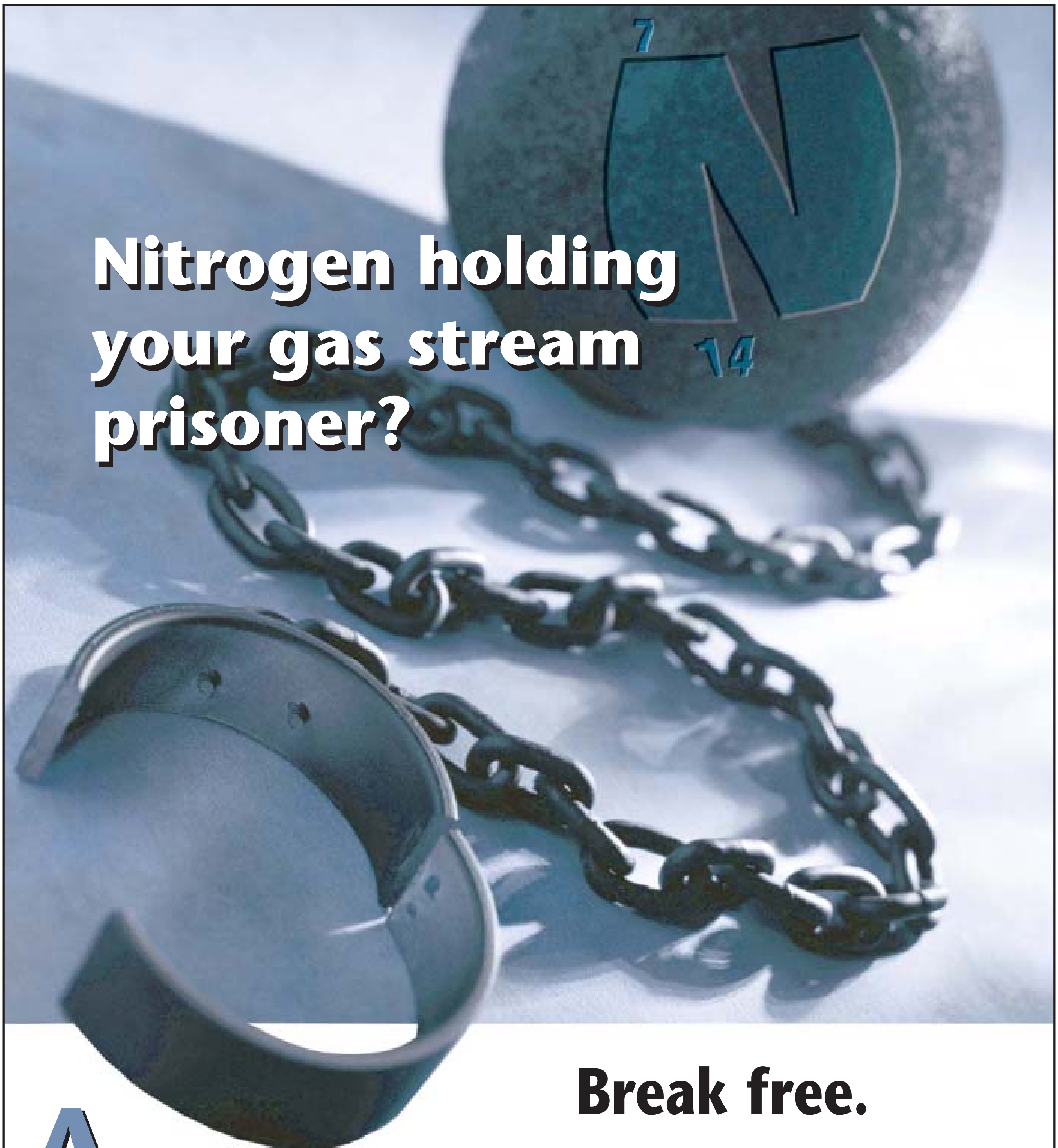
EOR/Heavy Oil Survey

Oil funds: threat or opportunity?
Williston's Bakken given 3-4 billion bbl recoverable
Moving caustic injection point helps crude unit operations
Field work cuts threat to suspended pipeline


Nitrogen holding
your gas stream
prisoner?
7
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14

OIL&GAS JOURNAL
Apr. 21, 2008
Volume 106.15

EOR/Heavy Oil Survey

Regular Features

Cover

Oxy Permian's Denver Unit CO_2 recovery plant in the Permian basin of West Texas processes associated gas and recycles CO_2. About 270 MMscfd (71% CO_2) enter the plant, with 230 MMscfd (90% CO_2) being reinjected for enhanced oil recovery (photo from Occidental Petroleum Corp.). As discussed in the EOR-heavy oil survey, p. 47, the number of CO_2 EOR projects has increased in the US, and the next 2 years will see more start up. The survey also notes that more steam-assisted gravity drainage projects are in operation for recovering bitumen from oil sands in Alberta. The photo above shows Petro-Canada's SAGD MacKay River central processing facility (photo from Petro-Canada).

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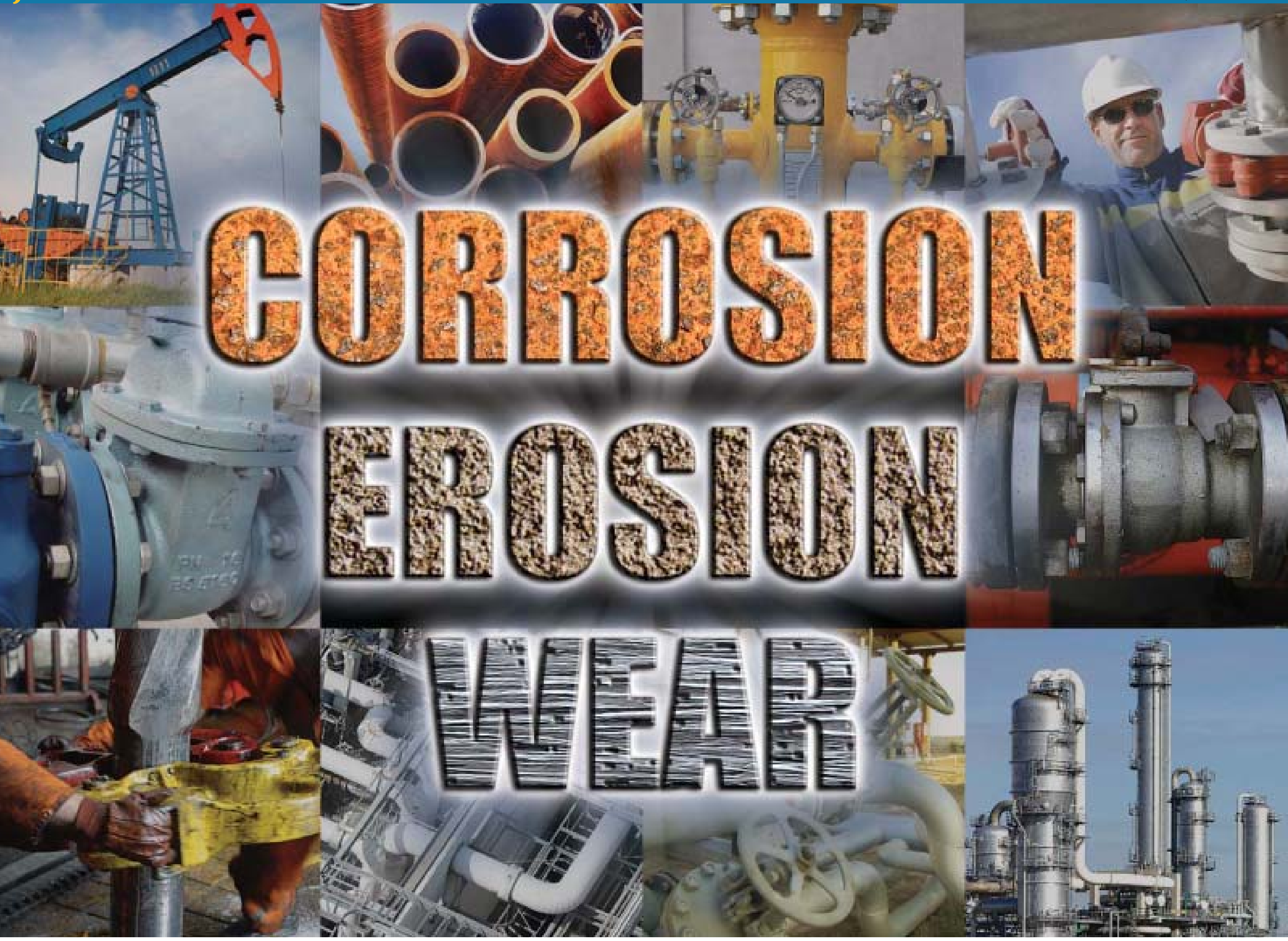

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It's a technological breakthrough...
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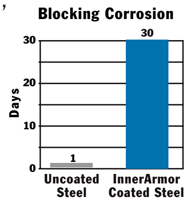
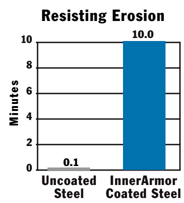
And InnerArmor has no porosity, no pinholes. So it creates a virtually impenetrable barrier against corrosion, erosion and wear.

Stopping corrosion
In NACE-standard TM185 sour autoclave testing, for example, InnerArmor withstood the maximum 30-day test—sustaining *no* attack or undercut.



While uncoated steel only lasted a single day!

Standing up to erosion
In the ASTM-standard G76 abrasive air-jet test, again, InnerArmor was easily able to go the full ten minutes—with *zero* surface damage.



By comparison, on uncoated steel the surface erosion began after only a few seconds.

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InnerArmor coatings can be created from a wide range of materials, and also in layers, for unprecedented sliding-wear properties and exceptional wear resistance.

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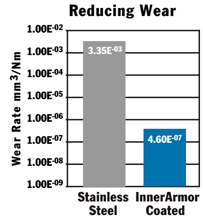

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General Interest

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Drilling & Production

Processing

Transportation

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Process Notes

Oil Sands Crude – Profits and Problems?

Canadian bitumen production currently runs about 1 MMbpd, with some being sold as Synbit and Dilbit. Over the next 10-12 years output is expected to increase to 3.5 MMbpd and more refiners will begin investing to process it and come to depend on the Synbit and Dilbit for a significant part of their supply. Few today, however, have ever processed these feeds at high blend ratios, and are unaware that conventional process and equipment designs are not up to the job. Canadian oil sands feedstocks are extremely hard to desalt, difficult to vaporize, thermally unstable, corrosive, and produce high di-olefin product from the coker. If you intend to lock into a long-term supply, therefore, it is imperative that you consider reliability and run length from a particular design.

Too low tube velocity in the vacuum heater tubes will lead to precipitation of asphaltenes. Too fast a flow rate will erode the tube bends. If coil layout, burner configuration and steam rate are not correct, run length will be measured in months, not years. Diluent recovery unit designs must take into account possible upsets from water slugs and other unpredictable situations that have damaged internals, resulting in diluent losses and high vacuum unit overhead condensable oil. Diluent is neither cheap nor plentiful, and high vacuum column operating pressure will reduce overall liquid volume yields. And if the design of the delayed coker fractionator is based on today's experience with conventional heavy feedstocks you will be lucky to run six months.

What all this means is that special process and equipment designs are needed to satisfy the special demands of processing oil sands crudes. Such processes are not generated by computer based designers who have little or no experience and never leave the office. They are developed only by engineers with know-how who have real experience wearing Nomex® suits and measuring true unit performance in Northern Alberta. Shouldn't this be kept in mind by those considering long term supply agreements?

For a discussion of factors involved in designing refinery units to process difficult oil sands feedstocks, ask for Technical Papers #234 and 238.

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General Interest — Quick Takes

Alberta adjusts 'New Royalty Framework'

The Alberta government, citing "unintended consequences" of its "New Royalty Framework," is easing terms for production from deep oil and gas wells.

Energy Minister Mel Knight said the government introduced two programs "to develop those oil and gas resources that are the most costly to access but offer the greatest potential."

As published last year, the New Royalty Framework will take effect next year and raise royalty receipts by 20% above the level projected under the previous regime in 2010 (OGJ, Nov. 5, 2007, p. 34).

Producers and analysts have warned that the increase will discourage drilling, especially for natural gas (OGJ, Mar. 17, 2008, p. 30). One of two new adjustments to the framework will offer exploratory wells deeper than 2,000 m as much as $1 million or 12 months of royalty offsets for oil production, whichever occurs first.

The other adjustment, for gas wells, applies to wells deeper than 2,500 m. Royalty relief will be applied on a sliding scale by depth, up to $3,750/m.

In other changes, the province will apply four par prices instead of two in calculations of oil royalties. Gas royalties will be calculated according to the sum of vertical drill depth and all laterals in an effort to encourage development of coalbed methane with lateral completions.

EU assured of Turkmen natural gas supplies

On a recent visit to Turkmenistan, European Union External Relations Commissioner Benita Ferrero-Waldner received assurances from Turkmenistan President Gurbanguly Berdimuhamedow that 10 billion cu m of natural gas would be available for EU members every year, beginning in 2009, the commissioner's spokeswoman Christiane Hohlmann told OGJ.

Hohlmann said this was the first time the president has given "a specific volume for these supplies, and such a 'political assurance' from one of the Central Asia's gas producers was very important."

The assurance of new gas supplies bolsters the EU's efforts to diversify its gas sources away from Russia's dominant position for reasons of both political security and safe supplies.

In a "Viewpoint" published in France's economic daily La Tribune, Ferrero-Waldner said the commission is "working with other partners" to enhance its gas supply security.

Agreements have been confirmed with Azerbaijan, Kazakhstan, and Ukraine. Besides Algeria in the south, "with whom we are negotiating a strategic partnership," she said, agreements had been finalized with Egypt, Morocco, and Jordan and when finalized with Libya "would open up serious prospects" of supply reinforcements from that country.

The commission, she said, is also studying new interconnections with the Middle East and North Africa, and an energy partnership is being discussed with Iraq. She said she would soon travel to Gulf Cooperation Council countries (Bahrain, Qatar, Kuwait, Oman, Saudi Arabia, and the UAE) to deepen the partnership with them.

UK farmin wells require $2 billion by 2010

Operators will need to invest over $2 billion over the next few years to develop 70 exploration prospects in the UK North Sea under farmin agreements, according to a new report published by consultancy Hannon Westwood LLP.

High rig rates have increased the level of investment, and the report said that more than 180 wells are scheduled to be drilled by 2010. Over the past 6 months, operators have moved towards discovery appraisal drilling. The UKCS holds a total future production potential of about 24 billion boe, including current production, existing development projects and discoveries, and exploration potential.

Other details in the report were:

- 25 wells are to be fully funded through farmin agreements.
- 12 wells are to be partially funded through farmin agreements to date.
- 70 wells are estimated to be partially or fully available for farm out by independent operators.

Chris Bulley, executive director at Hannon Westwood, said there was "a 25% plus turnover in farmin opportunities since the November 2007 report."

The UK government recently launched its 25th offshore licensing round with 2,297 blocks up for grabs.

Operators are seeking help for 35 of the farmin wells in the central North Sea. This has fallen from 50 in mid-2006 and 83 in late 2007. The southern North Sea has 18 farmin opportunities, while the northern North Sea and west of Britain have 9 and 8 respectively. ✦

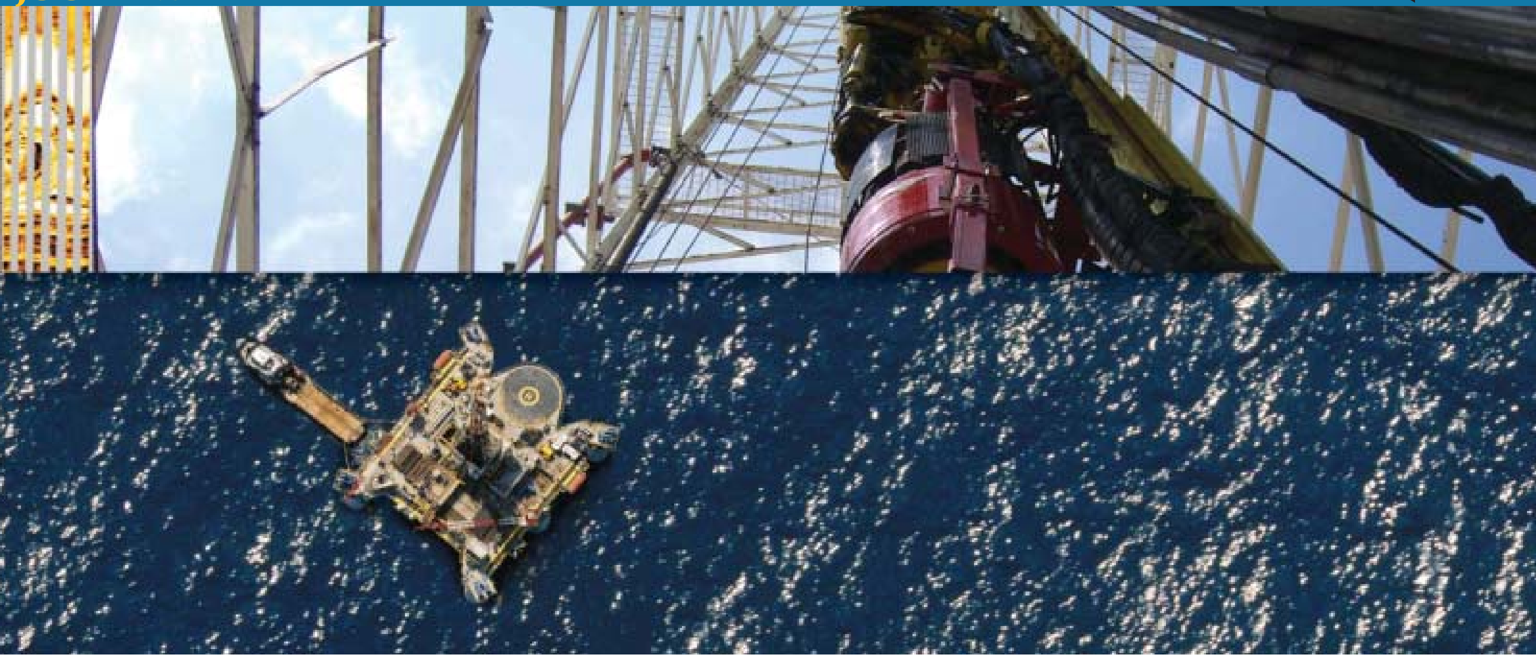
Exploration & Development — Quick Takes

Plains E&P strikes deal to develop off California

Plains Exploration & Production Co. reached an agreement with environmental groups in which Plains will phase out oil and gas production off Santa Barbara County, Calif., and in Lompoc Valley.

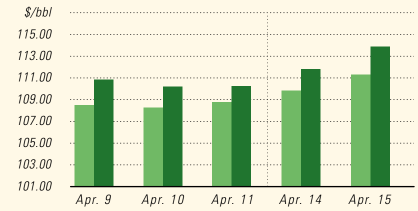
The Houston independent producer agreed to stop offshore production by 2022 and to shut down its Lompoc oil and gas plant in exchange for development of Tranquillon Ridge field off Lompoc.


Build better recovery.

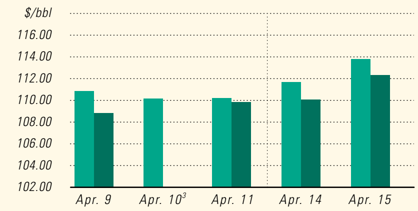


Industry Scoreboard

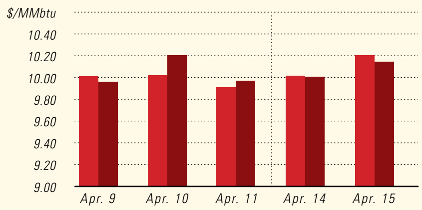
IPE BRENT / NYMEX LIGHT SWEET CRUDE



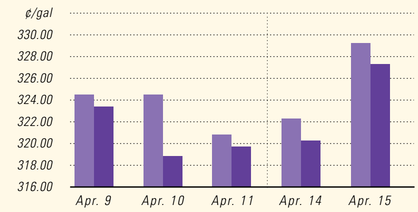
WTI CUSHING / BRENT SPOT



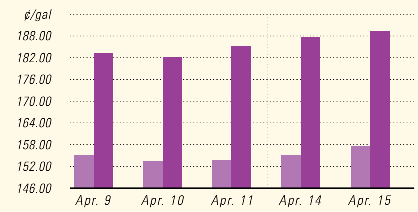
NYMEX NATURAL GAS / SPOT GAS - HENRY HUB



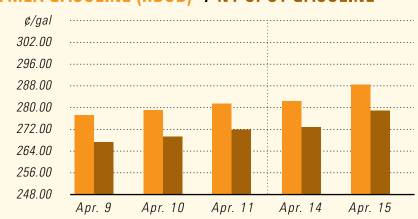
IPE GAS OIL / NYMEX HEATING OIL



PROPANE - MT. BELVIEU / BUTANE - MT. BELVIEU



NYMEX GASOLINE (RBOB)[1] / NY SPOT GASOLINE[2]



[1]Reformulated gasoline blendstock for oxygen blending. [2]Nonoxygenated regular unleaded. [3]Not available.

US INDUSTRY SCOREBOARD — 4/21

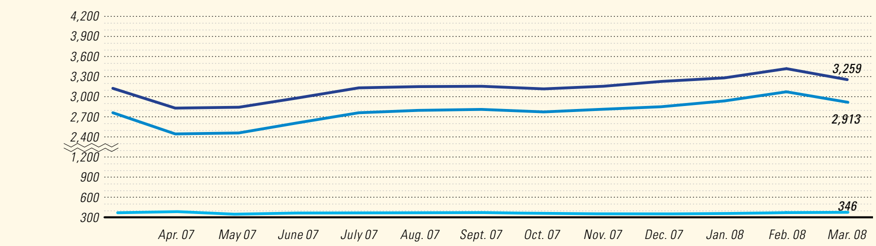
Latest week 4/4	4 wk. average	4 wk. avg. year ago[1]	Change, %	YTD average[1]	YTD avg. year ago[1]	Change, %
Demand, 1,000 b/d						
Motor gasoline	9,286	9,330	–0.5	9,028	9,035	–0.1
Distillate	4,465	4,232	5.5	4,283	4,386	–2.3
Jet fuel	1,534	1,565	–2.0	1,569	1,602	–2.1
Residual	747	564	32.4	1,569	1,602	–2.1
Other products	4,737	4,711	0.6	4,924	4,896	0.6
TOTAL DEMAND	20,769	20,402	1.8	20,344	20,764	–2.0
Supply, 1,000 b/d						
Crude production	5,097	5,087	0.2	5,080	5,176	–1.9
NGL production[2]	2,423	2,471	–1.9	2,408	2,306	4.4
Crude imports	8,912	10,283	–13.3	9,802	9,894	–0.9
Product imports	3,236	3,190	1.4	3,364	3,385	–0.6
Other supply[3]	1,310	902	45.2	1,134	881	28.7
TOTAL SUPPLY	20,978	21,933	–4.4	21,788	21,642	0.7
Refining, 1,000 b/d						
Crude runs to stills	14,648	14,872	–1.5	14,648	14,828	–1.2
Input to crude stills	14,827	15,221	–2.6	14,827	15,188	–2.4
% utilization	85.0	87.2	—	85.0	87.0	—

Latest week 4/4	Latest week	Previous week[1]	Change	Same week year ago[1]	Change	Change, %
Stocks, 1,000 bbl						
Crude oil	316,016	319,164	–3,148	333,399	–17,383	–5.2
Motor gasoline	221,268	224,710	–3,442	199,725	21,543	10.8
Distillate	106,027	109,720	–3,693	118,122	–12,095	–10.2
Jet fuel-kerosine	38,510	38,067	443	40,789	–2,279	–5.6
Residual	39,258	39,736	–478	39,352	–94	–0.2
Stock cover (days)[4]			Change, %		Change, %	
Crude	22.1	22.2	–0.5	22.4	–1.3	
Motor gasoline	24.0	24.5	–2.0	21.3	12.7	
Distillate	24.6	26.1	–5.7	27.1	–9.2	
Propane	19.5	18.1	7.7	20.6	–5.3	
Futures prices[5] **4/11**			Change		Change	%
Light sweet crude, $/bbl	109.74	103.49	6.25	64.51	45.23	70.1
Natural gas, $/MMbtu	9.91	9.68	0.23	7.54	2.37	31.5

[1]Based on revised figures. [2]Includes adjustments for fuel ethanol and motor gasoline blending components. [3]Includes other hydrocarbons and alcohol, refinery processing gain, and unaccounted for crude oil. [4]Stocks divided by average daily product supplied for the prior 4 weeks. [5]Weekly average of daily closing futures prices.

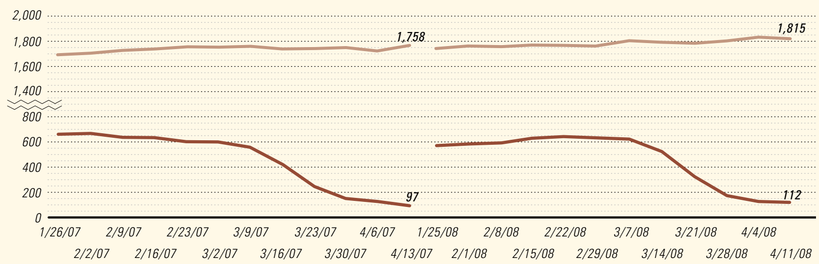
Sources: Energy Information Administration, Wall Street Journal

BAKER HUGHES INTERNATIONAL RIG COUNT: TOTAL WORLD / TOTAL ONSHORE / TOTAL OFFSHORE



Note: Monthly average count

BAKER HUGHES RIG COUNT: US / CANADA



Note: End of week average count

The Environmental Defense Center (EDC), Get Oil Out, and Citizens Planning Association of Santa Barbara negotiated the agreement.

The agreement remains subject to approval from regulators. The Santa Barbara County Planning Commission was scheduled to consider the agreement at an Apr. 21 meeting in Santa Maria.

If county officials approve the agreement, then it will go before the California Lands Commission, the California Coastal Commission, and the US Minerals Management Service.

Assuming all approvals are granted, Plains believes it could drill a well in the fourth quarter, a company spokesman told OGJ.

Terms call for curtailing production of existing oil and gas operations off Lompoc and Gaviota coast. Plains also agreed to donate land for parks.

EDC secured what it calls "an unprecedented agreement" from an oil company for zero net greenhouse gas emissions from the project. Plains agreed to contribute $1.5 million to a local fund for the purchase of hybrid buses.

Linda Krop, EDC spokeswoman, said the agreement stipulates that oil and gas development in both Tranquillon Ridge and Point Pedernales fields end Dec. 31, 2022.

The agreement followed Plains's proposal to expand its existing production from Platform Irene in federal waters (see Fig. 2, OGJ, Aug. 7, 2006, p. 20).

The proposed expansion would involve directional drilling from Irene into Tranquillon Ridge field in state tidelands between Plains's existing federal lease and the shore. Irene is in 242 ft of water 4.7 miles from land.

Santa Barbara County officials rejected a similar proposal in 2002 from Nuevo Energy Co. to develop Tranquillon Ridge field. Environmental groups opposed Nuevo's proposal.

To win the support of environmental groups, Plains offered to shut existing and new development operations in phases, all to be ended by or in 2022. This applies to the existing Point Pedernales project, Lompoc onshore oil fields, and the Point Arguello project, including platforms Hidalgo, Harvest, and Hermosa, and the Gaviota processing site.

Tofkat-1 strikes oil on Alaska's North Slope

The Tofkat-1 well struck oil-bearing sandstone in the Kuparak formation on Alaska's North Slope, said partner Bow Valley Energy Ltd.

Tofkat-1 awaits evaluation to determine its commerciality. Log analysis confirmed an interval of 10 ft of gross pay and 6 ft of net pay.

No oil-water contact was observed, and no production test was attempted. Brooks Range Petroleum Corp., the operator, drilled two sidetrack appraisal wells.

Tofkat-1 was suspended for possible re-entry as a future production well. The well is east of the Colville River (OGJ, Jan. 28, 2008, p. 42).

Partners are acquiring 210 sq miles of 3D seismic survey to be analyzed by late 2008 in preparation for an appraisal drilling program in the 2009 winter drilling season.

The 3D seismic will also be used to evaluate uphole potential in the Brookian formations.

Joint venture partners are Brooks Range Petroleum, TG World Energy Inc., Bow Valley Alaska Corp., and Ramshorn Investments Inc.

Apache lets contract for Devil Creek development

Apache Energy in Perth awarded the $260 million (Aus.) Devil Creek Development Project to Perth-based engineering firm Clough Ltd.

The work involves establishment of a shore plant to process gas from Apache's Reindeer gas field off Western Australia. Devil Creek is 65 km southwest of Karratha in the Pilbara region.

Clough will provide engineering, procurement, and construction for onshore facilities that will include gas processing trains, compressors, and accommodation facilities.

The plant will treat and dehydrate the gas, stabilize condensate content, provide storage and road load-out facilities for the liquids as well as gas compression and metering. The site will be connected by a short pipeline to the main natural gas trunkline from Dampier to Bunbury.

Apache said Devil Creek will be built for a capacity of 300 terajoules/day of gas. Phase 1 of the project will source gas from Reindeer at about 110 terajoules/day. The gas will be used for domestic supply in Western Australia.

Phase 2 expansion will come with the sanction of the Julimar field, which is still being appraised but which has a substantial gas reserve that will take the plant up to its planned capacity.

Liquids production is expected to be 500 b/d. Phase 1 will be on stream in early 2010 and Phase 2 probably in 2011. ✦

Drilling & Production — *Quick Takes*

StatoilHydro drills long horizontal Gulltopp well

StatoilHydro drilled and completed the 9,910 m-long horizontal Gulltopp well from the Gullfaks-A platform, in 439 ft of water.

Drilling began in April 2005. Gulltopp began producing this month from the shallow Brent reservoir at 2,430 m subsea. Platform rig contractor Seawell Ltd. drilled most of the wellpath at an inclination of 7°. In order to counteract the friction, Seawell filled the 8-km casing with air, instead of drilling mud, and "floated" the casing in the nearly horizontal well. "This was the key to success," said StatoilHydro.

The company had to upgrade the brake system on the drilling rig and the power supply for the platform in order to complete the well. StatoilHydro initially estimated the cost of drilling the extended reach well at $43.9 million, about 25% of the cost it estimated necessary to develop Gulltopp using a subsea template and dedicated multiphase flowlines (OGJ, Feb. 9, 2004, Newsletter).

StatoilHydro said in an Apr. 14 press release that the well was "considerably more expensive than initially assumed."

Gulltopp is in the Tampen area of the northern Norwegian North Sea, 5 km north of Gullfaks satellite fields Gullveig and Rimfaks. It's operated by majority owner StatoilHydro 70%, on behalf of license partner Petoro AS 30%.

Petrofac gets Syrian contracts worth $1 billion

Oil and gas facilities service provider Petrofac announced two major gas field development contracts with Syria worth a total $1 billion.

The first contract, worth $454 million, calls for construction of a plant to treat 4 million cu m/day of gas from Jihar field near Palmyra. The field is operated by Hayan Petroleum, which is a joint venture of Croatia's INA-Naftaplin and Syrian Petroleum Co. The plant is scheduled for completion in 2011.

Petrofac's scope of work includes engineering, design, and construction of gas processing facilities, an LPG recovery system, LPG storage and loading facility, gas gathering and collection systems, satellite gathering station, well sites, flow lines, utilities and offsite facilities, gathering pipelines, and living quarters.

The second contract, worth $477 million, was awarded by Petro-Canada for the processing of gas and liquids from the Al-Shaer and Cherrife fields in central Syria, which are expected to produce some 2.5 million cu m/day of sales gas and 150 tonnes/day of LPG from 2010. Sales gas and condensate will be fed into the Syrian pipeline grid, and LPG will be transported via tankers.

Petrofac's work scope includes engineering, design, and construction of a gas treatment plant, pipelines, gas gathering station flow lines, and well sites.

Iraq confers with majors to boost oil production

The Iraqi ministry of oil said it is in discussions with BP PLC, Chevron Corp., ExxonMobil Corp, Royal Dutch Shell PLC, and Total SA to increase production at several oil fields in the country.

Chevron and Total confirmed that their discussions were aimed at finalizing a 2-year technical support agreement to boost production at the West Qurna Stage 1 oil field near Basra. West Qurna has reserves estimated at 15-21 billion bbl.

The oil ministry intends to add 100,000 b/d to the field's current capacity of 180,000 b/d. Prior to the outbreak of war in Iraq in 2003, West Qurna had an estimated production capacity of 250,000 b/d. In December, Shell, BP, ExxonMobil, and Chevron submitted technical and financial proposals to develop five fields in southern and northern Iraq.

In addition to West Qurna, other areas include Rumaila and Zubair fields near Basra, Kirkuk oil field in the north, and Akkas natural gas field in the west.

Petrobras inks contract for Gulf of Mexico FPSO

Petrobras America Inc. signed a certified verification agent (CVA) contract with Det Norske Veritas (DNV) to ensure that the Gulf of Mexico's first floating production, storage, and offloading vessel meets US regulations.

The FPSO is expected to be installed in deepwater Chinook and Cascade fields in early 2010 with production scheduled to start during first-quarter 2010. The FPSO will have a storage capacity of 600,000 bbl of oil, a processing capacity of 80,000 b/d of oil, and natural gas export facilities of 16 MMscfd (OGJ, Jan. 14, 2008, Newsletter). Petrobras will build a pipeline to transport the gas to shore.

The FPSO will be installed in 2,600 m of water, which DNV said is among the deepest waters in which an FPSO has been installed. Both Chinook and Cascade fields are on Block 425 of the Walter Ridge area.

As the CVA, DNV will ensure that the project complies with US Minerals Management Services requirements. DNV is an independent foundation offering technology expertise to help safeguard life, property, and the environment.

Petrobras last fall hired BW Offshore Ltd. to convert, install, and operate the FPSO. The project also includes delivery and installation of a disconnectable submerged turret production buoy, including fluid swivel and an appurtenant mooring system to be supplied by BW Offshore's subsidiary Advanced Production and Loading AS. In the event of a hurricane, the turret and swivel will enable the FPSO to disconnect from its moorings and seek sheltered waters with minimum disruption to operations.

Technip was selected to provide engineering, procurement, construction, and installation of subsea facilities to develop the fields (OGJ, Jan. 28, 2008, Newsletter). Its Deep Blue and Constructor vessels will install five free-standing offshore hybrid riser systems for both fields along with infield flowlines and the gas export pipeline to shore. Work includes welding and installation of about 120 km of 6-in. and 9-in. steel pipelines, design and fabrication of 10 pipeline end termination, and 2 inline tees.

Petrobras is the fields' operator with 50% of Cascade and 66.67% of Chinook. Devon Energy Corp. owns the remaining 50% of Cascade, and Total E&P USA Inc. owns 33.33% of Chinook. ✦

Processing — *Quick Takes*

UK launches 2.5% biofuels transport requirement

Environmentalists and charities have criticized the UK government's requirement that all fuels must have 2.5% of biofuels, claiming the measure is raising food prices and damaging the environment through land conversion and increased usage of chemical fertilizers.

The new policy became effective Apr. 15 under the government's Renewable Transport Fuels Obligation (RTFO) to ensure that it meets European Union regulations. By 2010 the share will reach 5% and is expected to reduce carbon dioxide emissions by 2.5 million tonnes.

A spokesperson for the Environmental Transport Association said: "This initiative may be well intentioned, but it is highly flawed. Loopholes allow subsidized fuel from unsustainable sources to be certified. Companies are entitled to answer 'unknown' to the question of what the previous land use was and still be eligible for [an RTFO] certificate."

The Department for Transport will publish a report in June reviewing the use of biofuels, after which ministers may postpone or drop plans to increase the amount of biofuel in petrol and diesel to 10% by 2020.

Oxfam International warned that millions of indigenous people in Asia, Africa, and South America would lose their homes as land is cleared to build biofuel plantations such as palm oil.

But Jeremy Woods, leader of the biofuels working group at the Royal Society, said the RTFO could succeed if it promotes the best biofuels. This would be achieved by changing the RTFO to support the fuels with the lowest emissions by including a greenhouse reduction target.

"The RTFO helps send a message to industry that it is worth their while to significantly invest in improving existing biofuels and accelerate the development of new ones," he commented.

Soaring food prices have led India to curb rice exports, and higher fuel prices have also seen uprisings in Indonesia and Ivory Coast among other places. According to Oxfam, about 30% of recent food price inflation is due to biofuel production.

A survey commissioned by Friends of the Earth found that 9 out of 10 people did not know that their vehicles would now use renewable fuels.

Nippon Oil to shutter Toyama refinery

Nippon Oil Corp., Japan's largest refiner, will shutter its smallest refinery, the 60,000 b/d Toyama facility operated by subsidiary Nihonkai Oil Co. Ltd., according to press reports. The facility will be converted to a site for importing oil products from other Nippon refineries in Japan.

When the 40-year-old refinery on Japan's west coast is shut down by the end of March 2009, it will become the first Japanese refinery to be mothballed since 2003. The reasons for its closure include high costs, overcapacity, and diminished demand in the world's third-largest oil-consuming nation.

Closure was first considered last year because the refinery cannot process heavier grades of crude. The subsequent spike in crude prices has since reduced its profitability even more. ✦

Transportation — *Quick Takes*

TransCanada hoping to work with ANS producers

TransCanada Corp. said it will seek alignment with Alaska North Slope natural gas producers to build an Alaska natural gas pipeline, adding that it is unclear how a proposed joint pipeline by ConocoPhillips and BP PLC fits into requirements outlined by the state of Alaska.

TransCanada said it was "encouraged that two of the three producers are ready to advance the project and get Alaskan gas to markets in the Lower 48 states." ExxonMobil Corp. is the other ANS producer.

ConocoPhillips and BP announced Apr. 8 plans to build a 4 bcfd gas pipeline called Denali that would extend from ANS to Canada and potentially on to the US (OGJ, Apr. 14, 2008, p. 30).

BP and ConocoPhillips called the proposed Alaskan gas line the "largest private-sector construction project ever built in North America." They plan to spend $600 million over the next 36 months on an open season, which is slated to begin before year-end 2010.

TransCanada spokeswoman Cecily Dobson told OGJ Apr. 10 that TransCanada has sought for several years and continues to seek alignment with the three ANS gas producers and the state of Alaska. "We continue to believe that the alignment of these five parties is the best and fastest way to get the project completed," Dobson said. "If alignment with producers does not occur, this could turn out to be a competitive environment."

The TransCanada project is the only proposal sanctioned by Alaska's state government. TransCanada retains Canadian rights to an Alaska pipeline from approvals granted 30 years ago when the line was first proposed.

Alaska earlier this year adopted the Alaska Gasline Inducement Act (AGIA), legislation designed to advance construction of a gas pipeline from ANS. It requires a pipeline project builder to meet certain requirements that will advance the project, in exchange for a license that provides up to $500 million in matching funds.

These funds would help reduce the financial risks that such a huge project faces in its early stages.

Dobson said TransCanada is at stage two of the process and awaits Gov. Sarah Palin's decision whether or not to recommend TransCanada's project to the legislature. "We expect to receive the decision the week of May 19," Dobson said. "If recommended, our application would go to the legislature for approval. At this point, it's unclear on where [the] BP and ConocoPhillips proposal fits."

TransCanada gauges Pathfinder Pipeline support

TransCanada Corp. started a binding open season process to gauge support for a proposed pipeline that would move natural gas from US Rocky Mountains basins to Midwest markets.

The proposed 500-mile, 42-in. Pathfinder Pipeline will extend northeastward from Wamsutter, Wyo., through Montana and North Dakota to the Northern Border Pipeline Co. "at a location commercially attractive for delivery into the Ventura and Chicago area markets," officials said. Initial capacity is to be 1.2 bcfd, with an ultimate capacity of 2 bcfd. The project includes an option to build a 140-mile supply zone spur connecting Meeker, Colo., to Wamsutter. It is anticipated to be in service in late 2010.

To meet further growth in Rockies gas supply, TransCanada proposes later to extend Pathfinder 275 miles from the Northern Border Pipeline to Noyes, Minn., and Emerson, Man., where gas can be shipped to eastern markets or storage facilities using the Great Lakes Gas Transmission system and TransCanada's Canadian Mainline system.

"TransCanada is evaluating different options to move an increasing supply of natural gas from the Rocky Mountains," says Hal Kvisle, president and chief executive.

TransCanada will accept through May 22 binding bids for firm gas transportation capacity from Meeker and from Wamsutter to Northern Border Pipeline. TransCanada also is seeking nonbinding expressions of interests for the future extension of the pipeline to Minnesota and Manitoba.

A segment of the proposed line follows the same route as the proposed Bison Pipeline project. TransCanada is a partial owner in the Bison project through its interest in TC PipeLines LP. The two projects are coordinating preliminary field activities as they develop commercial support. Final design and location of Pathfinder will reflect the commercial support obtained, input of stakeholders, and the federal regulatory process. ✦

Calendar

✦ Denotes new listing or a change in previously published information.

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2008

APRIL

AAPG Annual Convention & Exhibition, San Antonio, 1 (888) 945 2274, ext. 617, (918) 560-2684 (fax), e-mail: convene@aapg.org, website: www.aapg.org/sanantonio. 20-23.

SPE Improved Oil Recovery Symposium, Tulsa, (972) 952-9393, (972) 952-9435 (fax), e-mail: spedal@spe.org, website: www.spe.org. 20-23.

ERTC Coking & Gasification Conference, Rome, +44 1737 365100, +44 1737 365101 (fax), e-mail: events@gtforum.com, website: www.gtforum.com. 21-23.

WestAsia Oil, Gas, Refining, & Petrochemicals Exhibition & Conference, Oman, +968 24790333, +968 24706276 (fax), e-mail: clemento@omanexpo.com, website: www.ogwaexpo.com. 21-23.

International Pump Users Symposium, Houston, (979) 845-7417, (979) 847-9500 (fax), website: http://turbolab.tamu.edu. 21-24.

SPE Progressing Cavity Pumps Conference, Houston, (972) 952-9393, (972) 952-9435 (fax), e-mail: spedal@spe.org, website: www.spe.org. 27-29.

MAY

IOGCC Midyear Meeting, Calgary, Alta., (405) 525-3556, (405) 525-3592 (fax), e-mail: iogcc@iogcc.state.ok.us, website: www.iogcc.state.ok.us. 4-6.

PIRA Canadian Energy Conference, Calgary, (212) 686-6808, (212) 686-6628 (fax), e-mail: sales@pira.com, website: www.pira.com. 5.

API International Oil Spill Conference, Savannah, Ga., (202) 682-8000, (202) 682-8222 (fax), website: www.api.org/events. 5-8.

Offshore Technology Conference (OTC), Houston, (972) 952-9494, (972) 952-9435 (fax), e-mail: service@otcnet.org, website: www.otcnet.org. 5-8.

GPA Permian Basin Annual Meeting, Odessa, Tex., , (918) 493-3872, (918) 493-3875 (fax), e-mail: pmirkin@gasprocessors.com, website: www.gasprocessors.com. 6.

PIRA Understanding Global Oil Markets Conference Calgary, (212) 686-6808, (212) 686-6628 (fax), e-mail: sales@pira.com, website: www.pira.com. 6-7.

ERTC Asset Maximization Conference, Lisbon, +44 1737 365100, +44 1737 365101 (fax), e-mail: events@gtforum.com, website: www.gtforum.com. 12-14.

Oil and Gas Pipelines in the Middle East Conference, Abu Dhabi, +44 (0) 1242 529 090, e-mail: c.pallen@theenergyexchange.co.uk, website: www.theenergyexchange.co.uk/mepipes8/mepipes8register.html. 12-14.

GPA Houston Midstream Conference, Houston, (918) 493-3872, (918) 493-3875 (fax), e-mail: pmirkin@gasprocessors.com, website: www.gasprocessors.com. 13-14.

International School of Hydrocarbon Measurement, Oklahoma City, (405) 325-1217, (405) 325-1388 (fax), e-mail: lcrowley@ou.edu, website: www.ishm.info. 13-15.

Uzbekistan International Oil & Gas Exhibition & Conference, Tashkent, +44 207 596 5016, e-mail: oilgas@ite-exhibitions.com, website: www.ite-exhibitions.com/og. 13-15.

NPRA National Safety Conference, San Antonio, (202) 457-0480, (202) 457-0486 (fax), e-mail: info@npra.org, website: www.npradc.org. 14-15.

IADC Drilling Onshore America Conference & Exhibition, Houston, (713) 292-1945, (713) 292-1946 (fax); e-mail: conferences@iadc.org, website: www.iadc.org. 15.

SPE Digital Energy Conference, Houston, (972) 952-9393, (972) 952-9435 (fax), e-mail: service@spe.org, website: www.spe.org. 20-21.

Mediterranean Offshore Conference & Exhibition (MOC), Alexandria, Egypt, + 39 0761 527976, + 39 0761 527945 (fax), e-mail: st@ies.co.it, website: www.moc2008.com. 20-22.

NPRA Reliability & Maintenance Conference & Exhibition, San Antonio, (202) 457-0480, (202) 457-0486 (fax), e-mail: info@npra.org, website: www.npradc.org. 20-23.

Society of Professional Well Log Analysts (SPWLA) Annual Symposium, Edinburgh, (713) 947-8727, (713) 947-7181 (fax), website: www.spwla.org. 25-28.

Middle East Refining and Petrochemicals Conference & Exhibition, Bahrain, +973 1755 0033. +973 1755 3288 (fax), e-mail: mep@oesallworld.com, website: www.allworldexhibitions.com. 26-28.

SPE International Oilfield Corrosion Conference, Aberdeen, (972) 952-9393, (972) 952-9435 (fax), e-mail: spedal@spe.org, website: www.spe.org. 27.

SPE International Oilfield Scale Conference, Aberdeen, (972) 952-9393, (972) 952-9435 (fax), e-mail: spedal@spe.org, website: www.spe.org. 28-29.

The CIS Oil and Gas Summit, Paris, +44 (0) 207 067 1800, +44 207 430 0552 (fax), e-mail: l.hannant@theenergyexchange.co.uk, website: www.theenergyexchange.co.uk/summit8/summit8register.html. 28-30.

JUNE

ERTC Management Forum, Copenhagen, +44 1737 365100, +44 1737 365101 (fax), e-mail: events@gtforum.com, website: www.gtforum.com. 2-4.

Caspian Oil & Gas Exhibition & Conference, Baku, +44 207 596 5016, e-mail: oilgas@ite-exhibitions.com, website: www.ite-exhibitions.com/og. 3-6.

Oklahoma Independent Petroleum Association (OIPA) Annual Meeting, Dallas, (405) 942-2334, (405) 942-4636 (fax), website: www.oipa.com. 6-10.

SPEE Society of Petroleum Evaluation Engineers Annual Meeting, Hot Springs, Va., (713) 651-1639, (713) 951-9659 (fax), e-mail: bkspee@aol.com, website: www.spee.org. 7-10

PIRA Scenario Planning Conference, London, (212) 686-6808, (212) 686-6628 (fax), e-mail: sales@pira.com, website: www.pira.com. 9.

Asian Geosciences Conference & Exhibition, Kuala Lumpur, +44 (0) 20 7862 2136. +44 (0) 20 7862 2119, e-mail: geoasia@oesallworld.com, website: www.geo-asia.com. 9-11.

Independent Liquid Terminals Association (ILTA) Annual Operating Conference & Trade Show, Houston, (202) 842-9200, (202) 326-8660 (fax), e-mail: info@ilta.org, website: www.ilta.org. 9-11.

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Managing a skills shortage

Uchenna Izundu
International Editor

For professional workers considering transfer into the oil and gas industry, conditions cannot be better.

An acute skills shortage is increasing operating costs and delaying project development. The slump of the oil and gas business and related job cuts in the late 1980s and early 1990s steered students away from petroleum disciplines. The industry now faces recruiting problems as its workload climbs and its workforce ages.

In the US, the number of enrolling undergraduate petroleum engineers hovered at 3,057 in 2007. Countries like China and the former Soviet Union continue to produce petroleum engineers, but importing talent from these countries creates cultural and linguistic issues.

The Global Talent Index by executive search firm Heidrick & Struggles warns that the US status as the world's biggest talent hotspot is under threat from the UK and China.

"Overall, the survey confirms that talent follows where money leads," the firm said. "After the US and UK, the next best countries for attracting and developing talent are relatively small but open economies of Canada, the Netherlands, and Sweden."

Big questions

According to the Society of Petroleum Engineers, the average age of the group's members worldwide is 47. The big questions are: Where will replacements come from? How can they be attracted and retained?

Rhys Jones, commercial director at headhunters Elliot Marsh Ltd., told OGJ that operators are conscious that their people are integral to success, particularly as the market has become so competitive. "They need to be more imaginative in their packages."

But finding new mid-level to senior managerial and technical staff was described by one headhunter as "absolute chaos." Finding and hiring staff can take months. "The demands are very high, and this varies depending on where you are and where you are going to. Salaries are jumping as an engineer can get £600/day for a job in Russia. If something goes wrong, he leaves to go to the next highest bidder, and turnover is high."

Brian Martin, founder of industry specialist search firm Opus Executive Partners, says oil companies must recruit talent from other industries such as aerospace, automotive, and utility to relieve the crisis.

"Professionals do exist, and you can mentor and technically train them to help their understanding," Martin says. "Historically, the industry feels its skills are unique and can be easily exported but not imported; this is no longer the case. Some technologies are genuinely proprietary to the industry. However, these are often developed in conjunction with external universities, further confirming that all kinds of intellect can and [are] being used by the industry."

Over the last 24 months, salaries for senior management and board appointments have risen by as much as 100%, according to Opus. Some companies recruiting new talent are shocked by the minimum salaries they are expected to pay before other benefits, such as pension plans, bonuses, stock options, and expenses are factored in.

According to a report by PricewaterhouseCoopers LLP, engagement metrics and measures for employers are important. In some cases, investors are using employee engagement levels to gauge a company's financial health and sustainability.

Research by PwC also shows that companies are willing to pay expatriate engineers from developing countries more than what they might expect from their country of origin by giving them a designated country rate. The disadvantage to employees is that they are denied pensions, share plans, mobility allowances, and other benefits so they can be moved on short notice. Some therefore may be cash-rich but lifestyle-poor—a trend not sustainable in the long term if employees are to be fully engaged.

According to Jones, one independent operator uses a points-based benefits system in which employees can create their own packages. "Each year, the employee will tick what they want to suit them at that stage: more holidays, higher pension contributions, gym membership, share options etc."

Phantom shares

Some public oil companies are experimentally offering phantom share options, in which an employee can receive cash equivalent to an increase in the value of a block of stock. Employees don't actually own the stock and can't exercise phantom options immediately. To date there has been no requirement to disclose such schemes in annual reports where senior management normally share extra earnings from stock options.

Oil companies are hungry for new technical employees, but can these trends of record salaries and slick benefits be sustainable in the long term? ✦

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Attention to future supply

Reports of major oil discoveries get quick attention from the general media these days, even when the discoveries aren't really news or, for that matter, discoveries. While the attention can be misleading, it shows welcome recognition that new quantities of hydrocarbons are important, especially when large. Yet some governments miss the message.

Remarks by a Brazilian official last week showed how eager the world seems to be for word of the next proverbial elephant. Haroldo Lima, general director of the National Oil, Natural Gas, and Biofuels Agency, told reporters Petrobras may have found "reserves" of 33 billion bbl in deep water off Rio de Janeiro. The price of Petrobras stock jumped. At least one analyst said the report disproved "peak-oil" pessimism.

'Reserves' premature

Trouble is, the discovery wasn't exactly news, and discussion of "reserves" is premature. Petrobras issued a clarification pointing out that its report of the discovery, in the Carioca area of the Santos basin, asserted the need for further assessment. It made that report last September (OGJ, Oct. 1, 2007, Newsletter). Only one well has been spudded since the discovery, and it hasn't reached target depth.

Without question, Petrobras and its partners have something important under way around Carioca and the earlier Tupi discovery nearby (OGJ, Nov. 20, 2006, p. 43). But it's too soon to suggest that this one area has reserves almost as large as all of Nigeria's.

In the ambiguous realm of oil and gas reserves, confusion is understandable. The industry that finds and produces fluid hydrocarbons, after all, has yet to agree even on a definition of the term. Enthusiastic officials and news reporters can be forgiven their occasional mishandling of the numbers.

It's the enthusiasm on display that's important here. Until recently, growth in volumes of recoverable oil, no matter how large, seldom made news outside the regional and trade press. Yet when the US Geological Survey raised its estimate of technically recoverable oil and gas in an expansive formation of the Williston basin this month, the headline "Billions of Barrels of Oil May Lie Under Northern Plains" showed up in, of all places, the New York Times.

The headline writer did justice to uncertainty. USGS assessed the undiscovered part of a specific resource, not reserves. Someone still must find the 3.7 billion bbl of crude oil, 1.85 tcf of natural gas, and 148 million bbl of gas liquids that USGS said might be technically recoverable from the Devonian-Mississippian Bakken shale in Montana and North Dakota. Quantities don't become reserves until the hydrocarbons are not only discovered but also determined to be technically and economically recoverable. Even then, they remain estimates.

The USGS assessment thus speaks probabilistically to the size of an exploratory target rather than to volumes relevant to immediate oil and gas supply. To supply years and decades from now, however, the assessment is crucial. The numbers are large. And the 25-fold increase they represent over a 1995 assessment of the Bakken shale testifies to the power of technology. The USGS report was indeed newsworthy, even if it had nothing to do with the general media's usual obsession: the price of gasoline.

Can it be that public attention has finally found its way to the connection between today's work and tomorrow's energy supply (and, therefore, price of gasoline)? If so, news organizations would perform a service by brushing the dust off estimates published by the US Minerals Management Service in November 2006 and promptly forgotten. The estimates are of technically recoverable resources in federal land inaccessible to oil and gas operators: 10.8 billion bbl of oil and 50.1 tcf of gas.

Potential supply

Those values equate to half of US oil reserves and a quarter of US gas reserves. They represent potential future energy supply, domestic and therefore secure, that the US deliberately shuns. They also represent possible income that the US denies Americans and receipts it denies governments.

Official foreclosure of these benefits, especially in the face of a faltering economy, deserves the attention of a vigorous press. It is, in fact, a scandal. ✦

Oil funds: threat or opportunity?

Gawdat Bahgat
Indiana University of Pennsylvania
Indiana, Pa.

The accumulation of large oil revenues, particularly since the early 2000s, has placed oil exporting countries among the world's largest sources of capital. The bulk of these assets are invested by government-owned and government-managed oil funds, which constitute a large component of broader sovereign wealth funds (SWFs). A recent Morgan Stanley study estimates that by 2015 the financial assets of oil funds and other SWFs will be about $6 trillion each.[1]

McKinsey Global Institute estimates that at the end of 2006, oil exporters collectively owned $3.4-3.8 trillion in foreign financial assets.

The Gulf Cooperation Council (GCC) states—Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the UAE—own $1.8 trillion—more than one third of these assets—according to an Institute of International Finance report in late 2007.[2 3]

In addition to older funds such as Kuwait's Future Generations Fund (1976), the UAE's Abu Dhabi Investment Authority (1976), and Norway's Government Pension Fund—Global (1990), the list of new funds includes Algeria's Revenue Regulation Fund (2000), Iran's Oil Stabilization Fund (2000), Kazakhstan's National Oil Fund (2000), Russia's Stabilization Fund (2004), Libya's Oil Reserve Fund (2005), Qatar's Qatar Investment Authority (2005), and Venezuela's National Development Fund (2005).

"By the late 1980s, Kuwait was earning more from overseas investments than it was from the direct sale of oil."

The general justification for these funds is that "some share of government revenues derived from the exploitation of a nonrenewable resource should be put aside for when these revenues decline" either from price fluctuations or resources depletion.[4] Thus oil funds generally are classified into two categories:

- *Stabilization funds.* These are designed to reduce the impact of volatile revenue on the government and the economy. When oil prices are high, the fund receives resources, and when prices are low, the fund pays out to the budget.

Stabilization funds are also meant to protect the economy from the so-called "Dutch disease." This term refers to Holland's experience in the 1970s, when a strengthening currency made it impossible for local manufacturers to compete. A flood of petrodollars may push up the value of the currency and undermine manufacturing competitiveness.

- *Savings funds.* These are designed to expand the benefits of oil wealth to the upcoming generations. The presumption is that oil revenues belong to all citizens of the exporting country, both current and future generations. Saving and investing a proportion of oil revenues would allow future generations to share oil wealth with the current one.

In most cases oil funds seek to achieve both stabilization and saving simultaneously.

Transparency concerns

In recent years, oil funds have injected billions of dollars into some of the world's biggest investment banks. Their high-profile activities include Abu Dhabi's acquisition of a stake in Citigroup and Kuwait's capital injection into Merrill Lynch. These investments are supposed to help stabilize financial markets.

In theory, international investment is welcome. However, when the source of the investment is a foreign government-owned fund, suspicions can arise. There are concerns that oil funds' investments might be driven more by political and strategic interests than solely by commercial benefits.

The huge and growing size of oil funds, the general lack of comprehensive investment strategies, and the low levels of transparency and accountability have further heightened these concerns.

Persian Gulf oil funds

In 2006 the Persian Gulf region held 61.1% of the world's proved oil reserves. Its share of global oil production was 30.1%, while its share of consumption was only 5.4%. The large gap between production and consumption and the massive proved reserves underscore the region's current and future oil revenues potential.

In the first half of this decade an estimated $542 billion of GCC international assets had been injected into global capital markets, mostly through investments by oil funds.[5]

Kuwait

Kuwait was one of the first countries in the world to set up an oil fund. In 1953, some 8 years before its independence from the UK, Kuwait founded an Investment Board Fund (IBF) in London to invest its surplus oil revenue.[6]

Shortly after oil discovery, the role of the state as the provider of basic services such as education and health care considerably expanded to meet the needs of a rapidly growing population. In an effort to organize public finance, the General Reserve Fund (GRF) was established in 1960 as the main treasurer for the government. The GRF received all revenues, including all oil revenues, from which all the state's budgetary expenditures were paid.[7]

In 1976 Crown Prince Jaber al-Ahmed al-Jaber al-Sabah, the deputy emir of Kuwait, issued Law No.106, under which the Future Generation Fund (FGF) was established. Article 2 stated, "A special account shall be opened for creating a reserve which would be a substitute to the oil wealth. An amount of 50% of the available state's general fund is to be added to this account." Article 1 stated, "An amount of 10% shall be allocated from the state's general revenues every year."[8]

In 1982 the government established the Kuwait Investment Authority (KIA) to manage the growing increase in oil revenues it allocated for investment. KIA assumed responsibility for managing and developing the financial reserves of the state's IBF as well as the FGF. The holdings in the former are mostly invested locally and regionally, while those in the latter are broadly diversified.[9] KIA's purpose is to "achieve a long-term investment return in order to provide an alternative to oil reserves, which would enable Kuwait's future generations to face the uncertainties ahead with greater confidence."[10]

KIA holds stakes in big corporations such as DaimlerChrysler and British Petroleum. In 1987 KIA bought more than 20% of then recently privatized BP. The British government became concerned about foreign ownership of such an important company, and KIA sold more than half of its stake.[11]

> *"The soaring of cross-border investment represents a potential structural shift in the global economy."*

In February 2008 KIA said it would invest $3 billion in Citigroup and $2 billion in Merrill Lynch as those two US banks scrambled for capital.[12] In July 2007, for the first time, KIA revealed the value of its holdings—$213 billion.[13]

This policy of investing oil revenues has proven crucial for Kuwait's financial welfare and political survival. By the late 1980s, Kuwait was earning more from overseas investments than it was from the direct sale of oil. Oil revenues were interrupted in 1990-91 as a result of the Iraqi invasion and occupation of Kuwait. The government and population in exile relied exclusively on investment revenues. These revenues also were used to cover international coalition expenses, postwar reconstruction, and repair of damaged oil wells and other facilities.

The UAE

With about $875 billion in assets Abu Dhabi Investment Authority (ADIA) is the wealthiest oil fund in the world.[14] ADIA invests the oil surplus of Abu Dhabi, the richest city-state within the UAE, which also includes Dubai.

ADIA was established in 1976 by Sheikh Zayed bin Sultan al-Nahyan, the founder of the UAE, and is currently chaired by UAE president Sheikh Khalifa bin Zayed al-Nahyan. The goal was to invest the Abu Dhabi government's surpluses across various asset classes. At the time, it was novel for a government to invest its reserves in anything other than gold or short-term credit.

In February 1977 Abu Dhabi Investment Co. was established by decree. The company was majority-owned by ADIA and National Bank of Abu Dhabi before ADIA's shares were transferred to Abu Dhabi Investment Council in 2007.[15]

The ADIA portfolio has always been diversified across regions and asset classes. Like other oil funds, ADIA has taken special interest in emerging markets in recent years, particularly in China and India.

While the recent decline in the value of the dollar is making investment in the US cheaper, many investors are holding back out of fear that the dollar will decline further, diminishing the value of their dollar holdings.

In addition, some oil investors are worried about potential political reactions. In 2006, DP World in Dubai, which is not a sovereign fund but a state-owned company, was blocked from taking over management of American ports. ADIA, which has always adopted a low profile investment strategy, learned from DP World's experience and is not likely to put itself in a similar situation.

In 2007 ADIA invested in private equity giant Carlyle Group and microchip maker Advanced Micro Devices. These large deals were subjected to intense scrutiny. In late November 2007 ADIA agreed to invest $7.5 billion in Citigroup but would have been keen to invest more. The deal gives ADIC 4.9% of the New York-based bank, making it

Selected OPEC members' net oil export revenues

Table 1

	Iran	Iraq	Kuwait	Qatar	Saudi Arabia	UAE	Total OPEC Nominal	Total OPEC Real (2000 $)
	Billion $							
1975	23.5	9.8	9.7	2.1	32.7	7.9	121.8	317.1
1976	25.0	10.1	9.7	2.3	38.3	8.9	133.7	329.0
1977	25.6	10.6	9.6	2.3	44.6	9.8	146.5	339.3
1978	23.3	11.6	10.3	2.5	39.4	8.8	138.0	298.6
1979	20.9	24.9	18.4	4.0	69.3	13.8	219.1	435.8
1980	13.0	27.7	18.6	6.0	113.5	20.3	296.3	544.1
1981	10.9	10.4	13.4	5.6	122.0	18.1	264.9	444.9
1982	18.7	9.8	8.4	4.0	69.7	13.5	191.3	302.2
1983	17.5	7.8	9.8	3.1	44.9	10.6	150.5	228.4
1984	14.7	9.9	10.6	4.1	39.3	10.4	147.8	216.5
1985	14.1	11.1	8.6	2.8	23.4	9.8	123.3	175.1
1986	6.0	6.6	6.2	1.4	18.6	5.5	71.2	99.0
1987	9.0	11.0	9.2	1.8	20.7	8.6	93.8	126.8
1988	6.8	11.4	6.8	1.7	20.2	6.7	82.2	107.6
1989	11.5	15.6	10.3	2.3	25.6	10.3	113.6	143.2
1990	16.5	9.9	6.5	3.1	43.4	15.0	147.4	178.5
1991	14.8	0.5	0.8	2.6	45.7	14.0	87.4	102.3
1992	14.8	0.7	5.8	2.5	45.5	13.0	127.9	146.6
1993	14.2	0.5	9.6	2.3	38.7	10.7	115.7	129.8
1994	13.5	0.6	10.2	2.4	41.1	11.0	122.7	134.6
1995	15.3	0.6	11.7	2.9	47.2	12.6	140.6	151.3
1996	19.2	0.9	14.1	4.0	57.1	15.8	175.7	185.4
1997	16.7	4.6	12.4	4.0	53.5	14.3	165.8	172.1
1998	10.7	6.5	8.1	3.4	34.8	9.8	112.4	115.4
1999	14.8	12.5	10.6	4.7	45.6	12.4	152.6	154.3
2000	24.3	21.1	18.3	8.1	76.3	21.5	258.6	256.1
2001	21.0	15.4	15.0	7.0	62.4	18.1	210.2	203.5
2002	18.5	12.7	15.0	6.9	57.8	17.8	197.2	187.4
2003	23.4	8.7	19.1	8.5	76.9	22.7	240.5	223.9
2004	32.3	18.4	26.3	12.5	103.6	29.7	336.8	304.5
2005	48.0	23.8	40.4	19.5	156.9	44.2	507.4	444.4
2006	54.6	31.8	50.0	24.4	182.8	57.5	612.7	520.8
2007	57.3	37.8	54.3	26.6	193.8	63.0	674.7	557.8

Source: Energy Information Administration, OPEC Revenues Fact Sheet, Mar. 12, 2008, (http://www.eia.doe.gov/emeu/cabs/OPEC_Revenues/Factsheet.html)

the largest shareholder, just below the 5% at which the US Federal Reserve has to take a look.[16]

Iran

Iran's Oil Stabilization Fund (OSF) was established in 2000. Like the other Persian Gulf states, Iran has enjoyed massive oil revenues since the early 2000s. But, unlike its Arab neighbors, the Islamic Republic has been under intense US economic sanctions since the 1979 revolution and more recently under UN sanctions. These sanctions have had negative consequences for the country's economic outlook, particularly the energy sector.

The tightening of economic sanctions in recent years due to Tehran's nuclear program has put more pressure on foreign banks not to provide loans and credit to Iran.

In December 2006 oil minister Vaziri-Hamaneh said, "Foreign banks are refusing to grant us capital or to participate financially in oil industry projects under various pretexts."[17]

One solution Iran's government is promoting is to dip into the OSF to finance oil and gas developments. Information on the actual level of the fund is difficult to access because the government has been drawing against it for various purposes.

The OSF does not show up in Iran's national budget. It is run as an account at the Central Bank by a handful of senior government officials.[18] In January 2008 Tahmasb Mazaheri, governor of the Central Bank, announced that the OSF holds $10 billion, much lower than other oil funds.[19]

Given this lack of transparency and high level of uncertainty, the OSF has been under investigation by the state inspectorate organization. Inspectors examine how OSF funds have been withdrawn and spent during the fourth 5-year development plan (2005-10).[20]

Assessing the poor performance of Iran's OSF, Jahangir Amuzegar, former finance minister in Iran's pre-1979 government, concludes, "Handling the OSF has shown the futility, if not indeed the absurdity, of setting up a rainy day fund if it can be freely used while the sunshine had never been brighter."[21]

Qatar

Qatar oil fund Qatar Investment Authority (QIA), founded in 2005 and headed by Prime Minister Sheikh Hamad bin Jassim al-Thani, manages about $50 billion.[22] It invests in international public markets, private equity, and real estate as well as nonenergy local strategic initiatives.[23]

In the last few years QIA has invested, or was involved in negotiations to invest, in several high-profile companies in Europe and the US. These include Credit Suisse, the London Stock Exchange, Nordic bourse (stock exchange) operator OMX, Nasdaq, British supermarket chain J Sainsbury, and Warsaw engineering firm European Aeronautic, Defense & Space Co.

In addition to investments in Europe and the US, QIA seeks investment opportunities in Asia, particularly China, Japan, Korea, and Vietnam. According to Kenneth Shen, head of strategic and private equity at the QIA, "Historically, we've been heavily invested in the US and Europe, and we've been underweight in Asia. We're going to increase our investments there, though not necessarily at the expense of Europe or the United States."[24]

Saudi Arabia

Unlike most of the other oil exporting countries, Saudi Arabia has not established an oil fund. Instead, the

kingdom's portfolio of foreign assets is held by the central bank and the Saudi Arabian Monetary Authority (SAMA). SAMA's investment policy has been conservative and largely limited to investment in bonds, especially US Treasuries and shares.[25]

However, SAMA Vice-Governor Muhammad al-Jasser announced that the kingdom will launch its first oil fund in the near future.[26] Furthermore, the growing tendency of oil funds in fellow Persian Gulf states to make more-aggressive investments is likely to be echoed in Riyadh, so SAMA likely will diversify its portfolio and begin to pursue riskier, higher-return investments.

Gulf investors bolder

From a brief review of oil funds in the Persian Gulf, several conclusions can be drawn:

• The sustained high oil prices since the early 2000s have substantially added to oil exporters' financial assets and convinced them to set up oil funds (Table 1).

• There is more diversification in investment paths compared with the 1970s and early 1980s. Persian Gulf investors increasingly are moving away from safe but low-return bonds to invest in alternative assets such as real estate, private equity funds, and hedge funds.

• More money is remaining within the broad Middle East, driven by several developments:

(1) The growing privatization of public enterprises in several Middle Eastern countries has created more investment opportunities.

(2) The proliferation of Islamic financial institutions has lured capital that previously would have been invested abroad.

(3) The concern about political backlash against Muslims and Arabs following terrorist attacks in the US and Europe has prompted oil funds and Muslim-Arab investors in general to invest in other assets outside of Europe and the US.

• Investments are diversified outside the US, although the US has the bulk of them. Europe continues to be a prime recipient, while Asia, particularly China and India, is emerging as an attractive target for both economic and political reasons.

• Most oil funds lack a clear comprehensive investment strategy, and transparency and accountability practices differ substantially from one fund to another, concluded a recent International Monetary Fund (IMF) study.[27] This conclusion applies to most oil funds in the Persian Gulf. Very little official information is made public on their investment portfolios. Most of their financial deals are pursued with little, if any, scrutiny by the public or legislative bodies.

HISTORICAL OIL PRICES

Table 2

	Brent, $/bbl		Brent, $/bbl		Brent, $/bbl
1976	12.80	1987	18.44	1998	12.72
1977	13.92	1988	14.92	1999	17.97
1978	14.02	1989	18.23	2000	28.50
1979	31.61	1990	23.73	2001	24.44
1980	36.83	1991	20.00	2002	25.02
1981	35.93	1992	19.32	2003	28.83
1982	32.97	1993	16.97	2004	38.27
1983	29.55	1994	15.82	2005	54.52
1984	28.78	1995	17.02	2006	65.14
1985	27.56	1996	20.76	—	—
1986	14.43	1997	19.09	—	—

Source: British Petroleum, BP Statistical Review of World Energy, June 2007, p. 16

Norway's pension fund

Norway's well-developed economy has greatly benefited from the utilization of its hydrocarbon resources. Table 2 shows the 30-year North Sea oil prices that have contributed to its prosperity. The country holds the largest proved oil reserves in Western Europe and in 2008 remains the world's fourth largest oil exporter after Saudi Arabia, Russia, and the UAE.

The Norwegian government in 1990 created the State Petroleum Fund (SPF), which was activated in 1995 following the achievement of overall budget surpluses.

In 2005 the SPF was renamed the Government Pension Fund (GPF). It was set up to manage Norway's petroleum wealth in a sustainable manner and to meet many of its rising pension and health expenditures. In 2008 the fund is valued at more than $350 billion.[28]

The ministry of finance delegated operational management of the fund to Norges Bank, a unit of the Norwegian Central Bank. A management agreement, which further defines the relationship between the ministry of finance as delegating authority and Norges Bank as operational manager, also has been drawn up.[29]

In managing the fund's assets Norges Bank has adopted a high-return, moderate-risk investment strategy. Thus, the fund's portfolio is divided into 54.6% fixed income and 45.4% equities.[30] Return on investment has averaged 4.6% since the fund's inception.[31]

Transparency

Norway's oil fund differs from those of most other countries in its strong emphasis on ethics and transparency. In November 2004 the government appointed the Council on Ethics, which established ethical guidelines for the fund. Comprehensive accounts and data on the fund's operations are easily available.

Quarterly and annual reports provide detailed information on portfolio valuation, composition, returns, management, transfers to and from the budget, market trends, risk exposure, and administrative costs.

Kristin Halvorsen, minister of finance, emphasizes the significance of transparency, saying, "We believe transparency is a key tool in building trust. It helps build public support and trust in the management of Norway's petroleum wealth. Openness about the fund's management can contribute to stable financial markets and exert a disciplinary pressure on managers."[32]

Russian Federation fund

Since the late 1990s Russia has emerged as one of the world's primary energy suppliers. Currently Russia is the world's largest natural gas producer and exporter and the world's second largest oil producer and exporter after Saudi Arabia. The prominent, growing role of the energy sector in Russia's economy raises concern about the most effective way to utilize the massive oil revenues that have accumulated since the early 2000s.

Addressing these concerns, the Russian government established a Stabilization Fund (SF) in 2004.

Three important developments laid the groundwork for the SF's creation:

- Although the state sold several major oil companies to oligarchs under Boris Yeltsin's administration, in Vladimir Putin's administration, the main emphasis was on restoring state power and ownership in energy assets—the so-called renationalization or deprivatization.
- The more-assertive Putin administration enjoyed substantial oil revenues due to soaring and sustained oil prices.
- Several Russian economists voiced concern that the deepening dependence on energy wealth is transforming the country into a mere raw material provider for the rest of the world and is hurting the competitiveness of other economic industries, particularly manufacturing, raising the threat of Dutch disease.

Following lengthy debates, the law establishing the SF was approved in December 2003 to resolve the challenge of how to manage the expanding pool of oil revenues.[33] Several sources contribute to the fund's revenues: a portion of the export duty on oil and petroleum products, part of the revenues from the severance tax on mineral resources, and a portion of the federal budget surplus at the beginning of the fiscal year. The law also set the base price at $20/bbl for Urals oil, above which revenues start accumulating in the SF. The fund is managed by the ministry of finance. In 2008, the SF's assets are about $157 billion.[34]

Investment strategy

From its inception SF ignited an intense debate on the appropriate investment strategy. Business leaders and regional governors spoke out in favor of boosting pensions and social benefits. They also called for utilizing the SF's assets for various investment projects and distributing them in the form of development loans. Former Prime Ministers Mikhail Fradkov and Yevgeny Primakov were prominent promoters of this approach.

On the other side, Deputy Prime Minister and Finance Minister Alexei Kudrin and many other economists opposed using the SF's assets in investment schemes, arguing that such spending would produce inflation, leading ultimately to the evaporation of the fund itself. Instead, they called for using the surplus revenues for early repayment of Russia's foreign debt.

> "The challenge Western financial markets face is how to ensure the steady inflow of badly needed investment while...addressing popular skepticism that these investments might be driven by strategic interests."

IMF supported the second approach, suggesting that saving oil revenues has served Russia well "as it has prevented even stronger inflationary pressures and much faster real ruble appreciation."[35] Putin and President-elect Dmitry Medvedev expressed similar approval.[36]

In his budget address in March 2007, Putin called for transforming the SF into two funds—a reserve fund and a national welfare fund.[37] This split took place in February 2008. The former will perform the same function as the old SF, accumulating energy profits and holding them in conservative investments to cushion the economy if energy prices fall. The latter will be used to fund shortfalls in the pension system and invest in riskier assets with higher returns such as corporate bonds and shares.[38]

Policy implications

Analysts have not reached a consensus on the benefits of setting up the oil funds that have proliferated in recent years. Few studies empirically test the efficacy of such funds. A March 2007 IMF study concludes that oil funds have "limited fiscal benefits and are largely redundant."

Oil funds have not been effective in addressing volatile exchange rates, it said. Instead, IMF suggests that any benefits could be achieved by "improving fiscal policy and administration."[39]

To ensure sound allocation of oil revenues, oil fund managers should integrate the funds with the budget, enhance coordination of the funds' operations with those of the rest of the economy, adopt a clear and comprehensive asset-management strategy, and establish mechanisms to ensure transparency and accountability, IMF said.[40]

A mounting anxiety

Equally important, oil funds' investments abroad have ignited a mounting anxiety over their commercial and strategic impact. Oil funds, as the Economist put it, are being "set up as the next villains of international finance."[41] The soaring of cross-border investment represents a potential structural shift in the global economy. Accordingly, economists and policymakers seek to assess the implications of this shift and the appropriate response.

The challenge Western financial markets face is how to ensure the steady inflow of badly needed investment while simultaneously addressing popular skepticism that these investments might be driven by strategic interests. Such skepticism might strengthen calls for protectionism and imposing restrictions on capital flows from oil funds and could weaken the overall global financial markets.

Addressing fears

To address this challenge, finance ministers from major industrial countries—Britain, Canada, France, Germany, Italy, Japan, and the US—met in October 2007 and called for an international code of best practices by government-owned cross-border investments, requiring greater disclosure of assets and actions. They also called on the World Bank and IMF to participate in setting rules.[42]

The Committee on Foreign Investment in the United States (CFIUS) is an interagency committee chaired by the US treasury secretary. It seeks to serve US investment policy through reviews that protect national security while maintaining the credibility of the nation's open investment policy. It also seeks to preserve the confidence of foreign investors and of American investors abroad that they will not be subject to retaliatory discrimination.[43]

In the US, the Foreign Investment and National Security Act of 2007 became effective in October 2007. It mandates additional scrutiny and higher-level clearances for transactions involving foreign government-owned investments. American officials say they have not seen any evidence of oil funds' seeking political leverage through investments.

In March, Abu Dhabi, Singapore, and the US reached an agreement on policy principles that would govern their funds' investments. The agreement guidelines stress that investment decisions should be based solely on commercial grounds. They also call for greater information disclosure, strong governance structure, and the creation of a predictable investment framework with no protectionist barriers and no discrimination among foreign investors.

The European Union faces the same challenges—how to welcome foreign investments from government-owned funds without compromising national security. Europeans are particularly concerned about Russia's use of its oil fund and government-owned oil and natural gas companies to buy pipelines and other energy infrastructure in Europe.

Unlike Washington, however, Brussels does not have a government mechanism such as CFIUS for scrutinizing foreign investments. The European Commission (EC) takes the view that among the EU and its 27 member states, comprehensive rules governing the activities of foreign investors already exist.

The EC prefers a voluntary approach rather than statutory tactics. In 2008 the commission proposed that each fund wanting to invest would be asked to disclose the size and source of its assets, the currency composition of its investments, and the regulation and oversight under which it operates in its home country. It would also be asked to provide public disclosure of its relationship with government authorities.[44]

The commission has not ruled out enacting a law to enforce these rules, however. EC Pres. Jose Manuel Barroso said, "We will not propose European legislation, though we reserve the right to do so if we cannot achieve transparency through voluntary means."[45]

Resistance to oversight

Calls to regulate these state-run investments will intensify, but a voluntary "code of conduct" instead of rigid and comprehensive rules could encourage foreign investment and smooth the progress of financial cooperation in the global economy.

Many funds, however, resist the pressure to embrace even a voluntary code of best practices on a number of grounds: First, they say, such a code seems unnecessary in light of their track records of abstaining from political interference. Second, the West's demand for regulation is said to be "hypocritical in light of the failure to regulate European and American banks and hedge funds."[46] Third, Western economies already have mechanisms to regulate foreign investments and prevent abuse by investors.

Anxieties are based less on actions than on suspicion amid such secrecy. Unlike Norway and a few other oil exporters, most oil funds continue to exhibit a low level of transparency and accountability. Despite this secrecy, no credible evidence exists that oil funds have pursued political or strategic gains.

Excessive regulations and a broad politicized hostility to oil funds would come at a high price—further deepening mistrust among oil exporters and Western markets. Instead, confidence-building measures and a free flow of capital, trade, and technology would benefit both sides and the overall global financial markets. ✦

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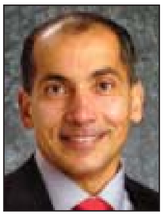
The author



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Impact of higher oil, product prices on US economy deepens

Nick Snow
Washington Editor

There are growing indications that high gasoline and diesel fuel prices are having an increasingly adverse impact on the general US economy, and federal lawmakers have started to respond.

US Sens. Maria Cantwell (D-Wash.) and Olympia J. Snowe (R-Me.) urged the Federal Trade Commission on Apr. 8 to use new regulatory authority it received as part of the 2007 Energy Independence and Security Act to prevent oil market manipulation. Two days later, House Republicans used floor debate on a beach protection bill to charge Democrats with not taking meaningful action in response to high gasoline and diesel prices.

Government statistics suggested that energy prices climbed more quickly in March. Wholesale prices for finished energy goods grew 2.9% during the month after increasing only 0.8% in February, the US Bureau of Labor Statistics said Apr. 15 in its latest Producer Price Index (PPI). More than half of the acceleration came from the survey's liquefied petroleum gas (LPG) index, which jumped 4.2% in March after dropping 9.7% a month earlier. The increase led to a 1.1% rise in the PPI for finished goods in March following growth of 0.3% in February and 1% in January, BLS said.

Prices for home heating oil and kerosine also rose last month after falling in February, while the indexes for diesel fuel and asphalt rose farther than in the previous month, according to the PPI. "Conversely, partially offsetting the acceleration in finished energy goods prices, the rise in the index for gasoline slowed to 1.3% from 2.9% in February. Prices for residential natural gas also rose less than a month earlier," the latest PPI said.

Bigger increases

But the energy price increases in March were greater further up the wholesale chain, according to the report. It said the index for intermediate energy goods climbed 5.9% last month following a 1.1% gain in February. "Leading this acceleration, the index for diesel fuel surged 15.3% after rising 0.9% in February. Prices for jet fuel, residential fuel, LPG, electric power, and home heating oil turned up in March," it said.

Gasoline prices slightly offset acceleration of the intermediate energy goods index by advancing 1.3% in March, compared with a 2.9% increase in February, the report continued. The utility natural gas index rose less than it did the previous month, it added.

For crude energy materials, March's PPI showed a 13.4% jump in the index following a 5.6% advance in February. It traced the bigger increase to a 17.5% jump in crude oil prices which followed a 0.6% rise a month earlier. Natural gas prices advanced slightly less than in February (11.4% compared with 11.5%) within the crude energy price index, it said.

Crude oil prices were the biggest uncertainty as the US Energy Information Administration issued its latest monthly short-term energy outlook Apr. 8. It said prices for West Texas Intermediate crude, which averaged $72.32/bbl in 2007, are projected to average $101/bbl in 2008 and $92.50/bbl in 2009.

"Based on the projections of weak economic growth and record high crude oil and product prices, consumption of liquid fuels and other petroleum products is projected to decline by 90,000 b/d in 2008 (a sharp reversal from the 40,000 b/d increase projected in the previous outlook), then increase by 200,000 b/d in 2009," EIA said. It forecasts that high retail prices and the current economic slowdown will reduce gasoline consumption by 0.4% to 9.4 million b/d during the summer driving season. Demand for distillate fuel, which includes diesel fuel and home heating oil, is not expected to change year-to-year, it said.

Consumer responses

Most consumers in 16 Midcontinent states are responding to higher motor fuel prices by driving less, according to Vincent F. Orza, dean of the Meinders School of Business at Oklahoma City University. The school's regular regional consumer sentiment survey also found in March that they were less inclined to buy durable household goods, while more believed their financial situation is worse than a year ago, he told an Apr. 9 hearing of the House Small Business Committee's Oversight and Investigation Subcommittee.

"At $3/gal, consumer discretionary income declines enough to impact the frequency of eating at quick service and casual theme restaurants, which alone are reported to have lost more than 10% of their customers. Soft good purchases at chain stores (many operating as small business franchises) and thousands of independent merchants are down along with ticket sales at movie theaters. This is a consequence of higher [gasoline] prices reducing the number of discretionary dollars," Orza explained.

Both major and independent retailers are closing outlets as a result, he continued. "Liz Claiborne is shuttering 54 Sigrid Olsen stores. Ann Taylor is closing 117 of its 921 stores. Talbot's has closed all of its men's and children's clothing stores along with 22 women's stores. Even Target and Starbucks are seeing a slowdown. Each of these chains are served by countless small businesses that provide window washing and custodial services, paper products, deliveries, alterations and many other services," he said.

The University of Michigan's Institute of Social Research, which conducts a better-known survey of consumer attitudes with Reuters, said more house-


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Trouble lurks in climate bill

A climate change bill that could reach the US Senate floor in June is already generating its own heat. Critics of S. 2191, which Sens. Joseph I. Lieberman (I-Conn.) and John W. Warner (R-Va.) introduced last year, warn that its provisions could lead to serious problems because it was pushed quickly through the Environment and Public Works Committee.

"It was not written until late October and was then rushed through the legislative process, when the oil and gas industry was included. The majority did not provide a summary of changes. Each time a new hearing was held, you had to read all 300 pages of the bill to find out what words had been changed," one insider told me.

Industry groups have been concerned about impacts of the bill's carbon cap-and-trade program. Some are worried that a provision involving natural gas carbon collection points could reduce domestic production.

"This has eclipsed all our other issues. If Congress makes the wrong choice for climate change and natural gas, the impacts could be devastating not only for our sector but for the general economy," said William F. Whitsitt, president of the American Exploration & Production Council.

Moved upstream

Paul Wilkinson, American Gas Association vice-president for policy analysis, explained that the collection point originally was at industrial plants or electricity generators. Sen. Frank R. Lautenberg (D-NJ) proposed moving it upstream. Putting it at the wellhead was considered too complicated so lawmakers placed it at the gas processing level.

Producers would need to spend billions of dollars already to buy carbon allowances, Whitsitt said. The amount could jump if processors build additional cap-and-trade costs into their rates, which would bite into producers' budgets, he told me.

Since most of its members are utilities, AGA's main concern is that the provision will increase costs for commercial and residential customers who already have made major progress in using gas more efficiently, Wilkinson said.

AGA proposal

AGA has proposed moving carbon-allowance collections back to their original point and not involving residential and commercial customers before 2020. At that time, the Environmental Protection Agency would analyze availability of other technologies and further efficiency gains by residential and commercial customers. "This also would solve upstream entities' problems with the point of regulation," Wilkinson noted.

"Increasingly, the senators and staff people we explain this problem to say this wasn't their intent," said Whitsitt. "So the question is whether they have the political will to do a 90°, if not 180°, turn now that this bill is so far down the road." It's critical that they do so, maintained Paul N. Cicio, president of the Industrial Energy Consumers of America. "The costs are incredibly high in this bill, and it could move more manufacturing out of the US. Natural gas is the low-carbon fossil fuel alternative. We should be encouraging, not discouraging, its production," he said. ✦

holds reported in March that their financial situation had grown worse than at any time since 1991, and more consumers cited high fuel and food prices as the main cause of their financial distress than at any time since 1982.

"Unlike the more widely shared experiences of a quarter century ago, lower income households have reported financial distress due to high fuel and food prices twice as frequently as upper income households," said Richard T. Curtin, who directs the monthly survey.

Orza told the House subcommittee that there is no short-term or easy solution to high gasoline prices. More exploration and refinery capacity would help, but government regulations and prohibitions make both more difficult, he said. "There is one quick fix that would benefit consumers and small business owners," he continued. "Congress could reduce federal fuel taxes, which would have an immediate positive impact of about 50¢/gal and would be quicker and easier than mailing rebate checks to 700 million households." ✦

US Senate adds renewable energy tax credit to housing bill

Nick Snow
Washington Editor

The US Senate approved an extension of renewable and alternative energy financial incentives as an amendment to a housing bill, HR 3221, by 88 to 8 votes on Apr. 10. The provision contains language identical to a bill that Sens. Maria Cantwell (D-Wash.) and John Ensign (R-Nev.) introduced earlier that week.

The provision differs from one in HR 5351, which the House approved on Feb. 27, because it would not be paid for by denying $18 billion of tax relief to major oil companies.

Its inclusion was appropriate in a

housing bill that aims to prevent excessive home foreclosures, Cantwell said following the vote. "The renewable and efficiency industries have been soaring, creating thousands of jobs and diversifying our energy supply. Newspaper headlines across the country have pointed to our country's rising unemployment and declines in the manufacturing and construction sectors," she said.

"One thing we can do to help Americans avoid foreclosure on their homes is to help them keep their jobs. By extending these tax incentives, we are not only providing certainty to these industries, infusing money into our economy, but creating high-paying, long-term jobs to help Americans get through these tough economic times," Cantwell said.

According to Ensign, the amendment would extend the place-in-service deadline through 2009 for the production tax credit that encourages electricity production from geothermal, wind, biomass, hydropower, and other renewable sources. It also would extend the solar and fuel investment tax credit for 8 years, he said.

"Today, we're hostage to skyrocketing energy prices. That's why it's so important that our bill is signed into law," Ensign said. "Without action, key incentives expire and much development toward renewable energy will slow. In some instances, it could stop. We only have a small window of time to provide the certainty needed to continue investing in, producing, and developing renewable energy," he said.

Pete V. Domenici (R-NM), ranking minority member of the Senate Energy and Natural Resources Committee, said while some members of Congress have advocated paying for a renewable energy tax credit extension with specific offsets, he believes that such taxes wouldn't be needed because the renewable energy tax credits will stimulate the economy.

"While I would prefer a longer term extension of the production tax credit, I am nevertheless pleased that the Senate was able to come together and craft this bipartisan measure," Domenici said. ✦

McCain backs halt of SPR crude purchases

Nick Snow
Washington Editor

US Sen. John McCain (R-Ariz.), breaking with the administration of President George W. Bush, urged the White House Apr. 10 to stop purchases for the Strategic Petroleum Reserve while oil prices are at record levels.

The announcement means that all

McCain calls for suspension of federal gasoline tax

Nick Snow
Washington Editor

US Sen. John McCain (R-Ariz.), the presumed 2008 Republican presidential nominee, called for a suspension of federal gasoline taxes from Memorial Day to Labor Day as an economic improvement measure.

"The effect will be an immediate economic stimulus, taking a few dollars off the price of a tank of gas every time a family, a farmer, or a trucker stops to fill up," he said in remarks scheduled for delivery Apr. 15 as part of a larger economic address at Carnegie Mellon University in Pittsburgh.

Suspending federal excise taxes would reduce retail gasoline prices by 18.4¢/gal and diesel fuel prices by 24.4¢/gal, according to the US Energy Information Administration.

The federal government should also suspend crude oil purchases for the Strategic Petroleum Reserve during that same period, he continued. "This measure, combined with the summer-long gas tax holiday, will bring a timely reduction in the price of gasoline. And because the cost of gas affects the price of food, packaging, and just about everything else, these immediate steps will help to spread relief across the American economy," McCain said.

But an environmental lobbying group said that the proposal to suspend motor fuel taxes raises more questions than answers. McCain's plan would cut $11 billion in highway funding that is critically needed, the League of Conservation Voters said.

"If Sen. McCain wants to save money for American taxpayers, he should get to the root of the problem: massive taxpayer-funded subsidies to huge oil companies that are already making tens of billions of dollars each year. The answer to the high cost of gas is not temporary tax maneuvering; it is a fundamental shift away from oil and towards clean, renewable energy," LCV President Gene Karpinski said.

House response

Following McCain's proposal, two leading Democrats on the House Transportation and Infrastructure Committee said suspending federal gasoline taxes this summer would do little good but cause significant harm.

The proposal would save most drivers less than $30 for the entire season while costing states $12 billion in highway construction, highway safety, and public transit funding, Chairman James L. Oberstar (D-Minn.) and Peter A. DeFazio (D-Ore.), chairman of the committee's Highways and Transit Subcommittee.

"This shortfall will have very real, devastating effects for hundreds of thousands of American families. McCain's proposal will eliminate approximately 300,000 family-wage, highway construction-related jobs. It comes at a time when, according to the Bureau of Labor Statistics, 1.2 million construction workers are already unemployed. In fact, the construction sector has the highest unemployment rate (12%) of any industrial sector," they said in a joint statement issued by the committee.

Suspending the taxes of 18.4¢/gal on gasoline and 24.4¢/gal on diesel fuel from Memorial Day to Labor Day, as McCain proposed, also would harm efforts to reduce highway congestion by eliminating necessary infrastructure improvement investments, Oberstar and DeFazio said.

"Despite its stated purpose, the proposal would actually do little for consumers. Instead, it is likely to turn into just another multibillion windfall profit for the oil companies," they said. This essentially happened in 2001, when Illinois and Indiana suspended their motor fuel sales taxes, they said.

"The McCain proposal is nothing more than an attempt to find a simple sound bit instead of a realistic solution," Oberstar and DeFazio maintained. "It brings to mind the words of H.L. Mencken: 'There is always an easy solution to every human problem—neat, plausible, and wrong.'"

three major presidential candidates now support the bill introduced Feb. 5 by Sen. Byron L. Dorgan (D-ND) that would suspend SPR purchases for the rest of this year, or until oil prices fell to $50/bbl or below.

Dorgan said Sens. Hillary R. Clinton (D-NY) and Barack Obama (D-Ill.), the two remaining major Democratic presidential candidates, expressed their support with other Senate Democratic Caucus members on Mar. 11 in a letter to Bush. McCain's backing "could encourage additional bipartisan support for my legislation," Dorgan said.

"All three presidential candidates now oppose the Bush administration program of putting nearly 70,000 bbl of oil underground every day," Dorgan said, adding, "The current policy puts upward pressure on [gasoline] prices and is not in the nation's interest. With oil prices at record highs and the SPR nearly full, it makes no sense."

McCain's announcement came a day after House Democratic Caucus Chairman Rahm Emanuel (D-Ill.) and two other House Democrats joined their Senate colleagues as they urged Bush to suspend SPR purchases when oil prices hit a record high.

"Today, oil and [gasoline] prices each hit record levels. The price of oil traded above $112[/bbl] on the New York Mercantile Exchange and the price of gas has now risen to a nationwide average above $3.34/gal," Emanuel said in an Apr. 9 letter, which also was signed by Edward J. Markey (D-Mass.), chairman of the House Select Committee on Energy Independence and Global Warming, and Rep. Peter Welch (D-Vt.).

The congressmen noted that the Department of Energy announced Apr. 4 it was going to continue filling the SPR and would solicit bids for 13 million bbl of additional oil. "Purchasing oil at these record prices to continue filling the SPR makes no sense. Furthermore, we should be acting to provide relief to consumers from high energy prices, not exacerbating runaway oil speculation by taking oil off the market," they told Bush.

DOE officials have said halting SPR purchases would have no significant impact on prices because they are such a small part of the total global oil market. ✦

LNG arrives at two new US terminals

Warren R. True
Chief Technology Editor-LNG/Gas Processing

Two LNG tankers arriving along the upper Texas Gulf Coast within 5 days of each other are delivering commissioning cargoes for two new LNG terminals, one in Louisiana and one in Texas.

On Apr. 11, the 145,000-cu m Celestine River docked at Cheniere Energy's Sabine Pass terminal, in Cameron Parish, La., along the Sabine River border near Port Arthur, Tex. The tanker had loaded its cargo at Nigeria LNG. On Apr. 15, the 138,000-cu m LNG regasification tanker Excelsior arrived at Freeport LNG Development LP's Quintana terminal, about 70 miles south of Houston. The LNGR tanker had loaded its cargo in Trinidad and Tobago, historically the largest LNG shipper to the US.

These two terminals, which will undergo cooldown over the next several weeks, and receive two or three more cargoes each in the process, will be the first land-based LNG terminals to open in the US in more than 25 years.

Two more US terminals, also in Louisiana and Texas, are in final stages of construction and expect to start up later this year or in first quarter 2009. ExxonMobil Corp.'s Golden Pass terminal lies across the Sabine River from Cheniere's terminal. And east of Sabine Pass, near Hackberry, La., 18 miles from the Gulf of Mexico, Sempra Energy subsidiary Sempra LNG is in the final months of building its Cameron LNG terminal.

New technology

When it starts up its Phase 1 later

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this year, Freeport LNG Development (FLNG) will have nominal sendout capacity of 1.5 bcfd with peak capacity of 1.75 bcfd.

Unlike the four existing US land terminals—at Everett, Mass.; Cove Point, Md.; Elba Island, Ga.; and Lake Charles, La.—that use submerged-combustion vaporization, FLNG employs an ambient-air system designed to draw heat from the air to regasify LNG. The process employs towers that consist of seven vaporizers with one installed spare employing vertical shell-and-tube exchangers of 250 MMcfd each.

The technology, says FLNG, allows the plant to operate within the Houston-Galveston nonattainment area because the towers emit no NO_x. During cooler weather, FLNG converts its vaporization process to heaters similar to those used at other LNG terminals.

Phase 1 has installed two, 160,000-cu m LNG storage tanks (3 bcf of gas equivalent in each tank) and an LNG carrier berth that can accommodate the largest carrier envisioned, according to the company. Phase 2, if decided upon, would add a third 160,000-cu m tank and separate berthing for a second carrier.

FLNG is managed by a general partner owned 50% by Michael S. Smith and 50% by ConocoPhillips. Limited partners with "economic interests," according to company material, are Smith, Cheniere Energy, Dow Chemical Co., and Osaka Gas. Company material says ConocoPhillips has agreed with FLNG for capacity rights of up to 1 bcfd. Dow has also contracted to receive 500 MMcfd.

Largest

Cheniere Energy's Sabine Pass terminal sits at the widest point on the Sabine River Navigation Channel and has two berths recessed far enough so that no part of the LNG vessel will protrude into the open waterway while docked, says company material.

Phase 1 construction has built 10.1 bcf of LNG storage in three tanks, each with an LNG capacity of 160,000 cu m and a maximum continuous regasification rate of 2.6 bcfd, the largest of any US terminal. Vaporization will take place in 16 high-pressure submerged combustion vaporizers. Takeaway is provided by a 16-mile, 42-in. pipeline.

Two or three more cargoes, from suppliers yet to be announced, will complete the cooldown process. Commercial operations are likely to start in May or early June, abut as yet no supply contracts or spot supplies have been announced. Phase 2 is under way and will add 1.4 bcfd with three more 160,000-cu m single-containment tanks, 16 ambient-air vaporizers, each with a high-pressure sendout pump, and 8 more SCVs, also aided by a high-pressure sendout pump. ✦

Global offshore drilling spend to reach $80 billion by 2012

Over the next 5-year period to 2012, high oil prices will continue to drive oil and gas industry spending on offshore drilling to a total of $380 billion. This is an increase of nearly 60% compared with the $240 billion spent in the previous 5 years, according to a forecast released by Douglas-Westwood Ltd. and Energyfiles.

The latest edition of the "World Offshore Drilling Spend Forecast 2008-12," released Apr. 14 by the two research firms, forecasts that by 2012 the global drilling market will be worth an estimated $80 billion, more than doubling since 2003.

Based on data derived from Energyfiles' global database, nearly 18,000 offshore wells were drilled over the last 5 years. "The forecast for the next 5 years is generally stable but with a peak in 2010 and a slight dip in 2011, ultimately equaling a little over 20,000 for the period, and representing a rise of 13%," the forecast said.

Currently, Asia is seeing the highest activity, followed by North America and then Western Europe, the forecast said. "These areas are expected to continue to see higher drilling levels although average numbers will decline significantly offshore Western Europe," said Michael R. Smith, report author with Energyfiles.

"With oil prices more than quadrupling over the past 5 years," said Steve Robertson with Douglas-Westwood, "drilling rig utilization has reached close to 100% and maximum day rates have soared from $225,000 to more than $520,000, with a future contract agreed at $637,000 for a latest generation deepwater rig."

Deep waters rising

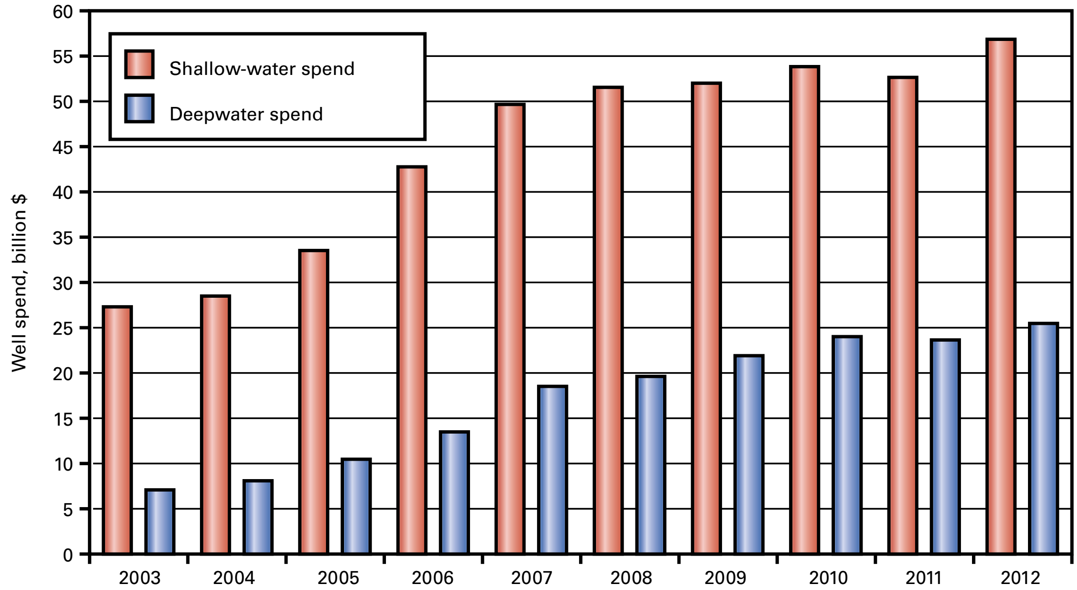
Substantial growth, the forecast said, is taking place in deep water. In 2007 it is estimated that nearly $50 billion was spent on shallow-water drilling compared with $18 billion in the deep water. However, by 2012, deepwater spending is expected to rise by more than 40%, while spending on shallow-water drilling is expected to increase by just 6%.

"Despite today's political environment there are still lots of offshore opportunities," Smith said. Even within the Organization of Petroleum Exporting Countries, Smith said, "activity is now increasing." For example, Nigeria, Indonesia, and Angola—the three OPEC countries with deepwater potential—are promoting outside investment into their deepwater basins, Smith said, adding, "And countries around the Persian Gulf are drilling many more shallow-water wells, as well as encouraging foreign companies to develop their huge gas reserves."

Smith said shallow-water development spending in the near future "will be generally flat although will show modest gains after 2010." Some areas, however are seeing increases, he said, such as the Persian Gulf and in Russia and Azerbaijan, "where unexploited areas are being developed in massive, long-term schemes."

Increasing more rapidly still, deepwater development drilling is increasing rapidly "in

Spend for shallow and deepwater offshore wells



Source: Douglas-Westwood and Energyfiles all regions," Smith said, "where fields have been discovered, supported by the many ultradeepwater projects now proceeding, especially in West Africa, Brazil, and the Gulf of Mexico."

Smith concluded, "Though rigs have increased their relative share of drilling spend, the money is not just being spent there. In 2007 it is estimated that 37% of expenditure was billed by the rig contractors, just over a fifth was earmarked for support, 6% went towards geoscience, and the remainder went towards well engineering.

"But as the industry probes more complex geology, spending on anything related to longer and more tortuous well paths is expected to grow disproportionately to other technologies," he said. ✦

Environmental challenges predominant theme at oil summit

Doris Leblond
OGJ Correspondent

Oil and natural gas exploration and development and its relationship to the environment was a predominant theme at the 9th Annual International Oil Summit Apr. 10 in Paris. Organized by Institut Francais du Petrole (IFP) and consultant and publisher Petrostrategies, the summit presented varied subjects, most of which contained an environmental dimension.

In a keynote speech, Saudi Arabia Minister of Petroleum and Mineral Resources Ali I. Al-Naimi said a major challenge for the oil and gas industry is to "reduce emissions from fossil fuels while managing the cost of such reductions and their possible negative impact on economic growth and human prosperity."

Al-Naimi said protecting the environment and promoting human prosperity "go hand in hand." He insisted that "those of us in the energy sector, and particularly the petroleum industry, have a particularly important role to play in addressing these challenges." It was also, he said, "a task not only for the fossil fuels industry but also for national governments, universities, research institutions, and cross-border organizations."

Al-Naimi dismissed the role of biofuels as a solution to solving the emissions problem, blaming them for being unfriendly to both the economy and the environment. Instead he advocated renewables, especially solar energy which Saudi Arabia intends to develop.

But what he favored most was development of carbon capture and storage as "a promising method for reducing emissions from fossil fuels in which he included "conventional oil, natural gas, coal, tar sands, and oil shale among others."

He said this is the way fossil fuels "can be and should be made environmentally friendly sources of energy, particularly as they will continue to meet the lion's share of energy needs for the foreseeable future."

IOCs, NOCs

In their addresses, both Malcolm Brinded, executive director of exploration and production for Royal Dutch Shell PLC, and Christophe de Margerie, Total SA's chief executive officer—the only international oil majors present—shared this view but also had much to say about relations between international and national oil companies, promoted to a fully fledged theme at this conference.

Brinded's "Blueprint for a shared future" calls for energy industries to respond to three "interrelated" challenges: meeting expanding energy needs, getting more from increasingly difficult resources, and cutting carbon emissions. He advocated "lobbying for a global carbon market that will enable carbon emissions—particularly from coal—to be mitigated more efficiently, and allow carbon space for the oil the world uses so effectively in transportation."

The key to achieving this, Brinded said, was "partnership between national and international oil companies."

De Margerie insisted that, because of the trend in current oil prices, "it is high time to stop opposing energy and climate change." His clear message was: "It is time to move" towards "a new model" to cope with rising oil and gas demand "because of the risk of supply and demand crossing sooner than expected" if OPEC fails to see the need for more oil; to improve dialogue and cooperation with host countries; and deal with technical and financial challenges but also to work to help oil-producing countries reduce their carbon footprint from oil production.

For De Margerie "dialogue and cooperation with host countries is more than ever necessary, but the message has only been partially received." There are still 45% proved oil reserves in "closed" countries, he noted. Meeting people's expectations in those countries through jobs, training, community development, and better governance is not enough.

"We must go further and open a debate, which has to be political, talk about real matters. We have heard for years that the market will balance supply and demand. Now we need to be all together to produce more spare capacity," De Margerie urged.

However, even though Sonatrach Pres. and Chief Executive Mohammed Meziane, speaking on behalf of Algeria's energy minister and current OPEC Pres. Chakib Khelil, agreed with Al-Naimi that NOCs and IOCs should "join their efforts along the value chain for closer cooperation." Yves-Louis Darricarrere, Total's exploration and production president, admitted that there are "different countries, different NOCs, and different expectations."

And "NOCs today are knowledge-able, capable, and confident. They don't depend on IOCs," Brinded pointed out.

For IFP Pres. Olivier Appert, "the scene is changing, and the way to cooperate depends on the many different local conditions for NOCs. The way to cooperation has not yet been found. We shall have to wait for our next Oil Summit to see how things have evolved," he said.

Oil prices

What has changed since 2002, rightly pointed out Nader Sultan, former KPC chief executive, are the high oil prices. And looking further ahead, he wondered whether it might not be possible now for an NOC to buy Unocal Corp. "It makes sense now, he said, for NOCs and IOCs to have joint ownership: one day NOCs will be able to buy IOCs.

Broaching the highly topical matter of high oil prices, Fatih Birol, the International Energy Agency's chief economist, saw them opening up "a new world order" as he put the crucial question: "What role for prices?" IEA, he said, is working on a study it will release in November linking thoughts on the oil price to oil and gas supply in the years to come.

The point of departure, he said, is the declining price elasticity of supply and demand—bad news for everyone, he added. In fact, the price effect on demand is diminishing because in China, India, and oil-producing countries, oil subsidies are as high as $50/bbl/year.

Economic growth is soaring in all three areas and coming mainly from the transport sector where there is little scope for change in the short and medium term. This is why the price effect is diminishing.

As for the Organization for Economic Cooperation and Development area, it is getting richer, and the share of money going into energy has been halved over the last 20 years. High taxes also cushion high oil prices.

Declining demand elasticity is matched by declining supply price elasticity as costs increase and lower the propensity to invest among major resource holders. "Price may increasingly play a 'clearing' role indirectly through its impact on the pace of economic growth," he concluded.

For the present, said IEA Executive Director Nobuo Tanaka, there is no single explanation for higher oil prices, which he persisted in seeing as "too high." Are they due to the large increase in money flows, higher costs of materials, the short-term influence of a weak dollar (even though oil prices are high in all currencies, he pointed out), or lack of data on stocks, which aggravate volatility?

Eric Watkins, Senior Correspondent

Questions loom over ESPO line

How long have we been hearing about Russia's East Siberia-Pacific Ocean (ESPO) pipeline project? The debate has been interminable. Even as far back as 2005, Russian officials were fuming about lack of progress.

That's when Russian Prime Minister Mikhail Fradkov, in an effort to speed implementation of the project, directed relevant ministries and departments to prepare a detailed proposal by Nov. 10 of that year.

Fradkov had signed a resolution on Dec. 31, 2004, to construct the pipeline, with state-run OAO Transneft as its designer and builder.

Stages planned

The first stage of the project called for a 2,400-km oil pipeline from Taishet to Skovorodino, near the border with China, along with a rail oil terminal on Perevoznaya Bay. The second stage involved construction of pipeline from Skovorodino on to Nakhodkha on the Pacific Coast.

Back in August 2005, Boris Govorin, governor of the Irkutsk Region, even said Russia would soon begin construction of the first phase of the pipeline from Taishet (OGJ Online, Aug. 10, 2005).

Later that year, though, Fradkov seems to have lost patience. "The setting up of the Eastern Siberia-Pacific Ocean pipeline system has dragged out without good reason," he said. "One of the priority projects for the country's economic development is practically not being implemented."

Where are we now? It's 2008, and on Apr. 16 government sources said Russia's Federal Tariff Service (FTS) would have to approve the highest possible tariff for pumping oil along the ESPO line due to the "apparent unprofitability" of the project.

Unprofitable project?

Huh? Can anyone imagine that the line would be unprofitable in these days of rising prices around the globe? Well, believe it or not, the Russians are actually suggesting that no tariff proposed by Transneft or the tariff service will cover the expenses because delivery volumes will be limited.

"Given the estimates produced by Transneft any figure will be unprofitable in relation to this project. If all current expenses are divided by the volumes, the figure may come to $1,000 for a tonne; therefore, FTS will have to set the highest possible rate," a government source said.

Significantly, those rates coincide with the latest round of discussions between the Russians and Chinese regarding the ESPO project. The two sides Apr. 15 decided to develop project documentation for the construction of a pipeline spur from the main ESPO line to China.

"For now, all project work has practically been concluded," said Russia's Deputy Industry and Energy Minister Andrei Dementyev. "If China agrees with Russian partners on supplies and on the volume of oil, then they will make a decision on the beginning of construction of this branch," said Dementyev. "Neither Transneft nor China seeks to build the pipeline so that it should be idle."

Practically concluded? It's just the small matter of a large financial guarantee that is stopping the work. ✦

"At the IEA, he elaborated, we do believe that the many explanations stem from the coming together of different factors, including the low level of spare oil capacity and the continuing mismatch of refining capacity."

The final oil summit session featured service companies, whose challenges were a fitting cap for the whole oil industry's growing problems.

One problem they did not have, however, was a scarcity of projects. Technip's president Thierry Pilenko mentioned having to cope with 170 "megaprojects" of increasing complexity and size during 2007-10. These billion-dollar projects, he specified, required specific skills and new frontier technologies.

As Schlumberger's EAF Pres. Satish Pai summed up: access to reserves-resources required experienced people and innovative technology, while decline and reservoir complexity is driving technology development.

All to be achieved with rising costs and—a key challenge for the industry—lack of skilled "human capital," especially in the area of strong project management capabilities, said Technip's Pilenko, while Saipem's Pres. Pietro-Franco Tali explained that these challenges must be overcome through "a global approach."

For instance, Schlumberger has recruited over 6,000 engineers from 200 universities in 80 countries, and training them will form a "major part of the 400,000 training days targeted in 2008."

Saipem for its part is adding 1,000 people in Malaysia and adding another 1,000 in India, where another Saipem is being replicated for added value, acting on the assumption that "companies should invest in central hubs where you put experienced people." Also crucial is large investment in "the right type of assets" for the future.

And central to all these policies lies the commitment to "sustainable growth" and dealing with environmental problems right from the early project design stage and beyond. ✦

Williston's Bakken given 3-4 billion bbl recoverable

Alan Petzet
Chief Editor-Exploration

The Upper Devonian-Lower Mississippian Bakken formation in North Dakota and Montana, which has produced 105 million bbl of oil through the end of 2007, contains an estimated 3 to 4.3 billion bbl of undiscovered, technically recoverable oil, the US Geological Survey said Apr. 10.

This is 25 times the USGS 1995 assessment of the amount of oil that can be recovered from the formation. It is "larger than all other current USGS oil assessments of the Lower 48 states and is the largest 'continuous' oil accumulation ever assessed by the USGS."

The next largest continuous oil accumulation in the US is in the Cretaceous Austin chalk of Texas and Louisiana, with an undiscovered estimate of 1 billion bbl technically recoverable.

The mean value for the Bakken is 3.65 billion bbl of oil, 1.85 tcf of associated-dissolved natural gas, and 148 million bbl of natural gas liquids. This volume is judged to be producible using available technology and industry practices.

"New geologic models applied to the Bakken formation, advances in drilling and production technologies, and recent oil discoveries have resulted in these substantially larger technically recoverable oil volumes," the USGS said.

Five continuous assessment units (AU) in the southern Williston basin were identified and assessed. They are, with mean resource values: Elm Coulee-Billings Nose 410 million bbl, Central Basin-Poplar Dome 485 million bbl, Nesson-Little Knife Structural 909 million bbl, the Eastern Expulsion Threshold 973 million bbl, and the Northwest Expulsion Threshold 868 million bbl.

At the time of the assessment, a limited number of wells have produced oil from three of the assessment units: Central Basin-Poplar Dome, Eastern Expulsion Threshold, and Northwest Expulsion Threshold.

"There is significant geologic uncertainty in these estimates, which is reflected in the range of estimates for oil," the survey said.

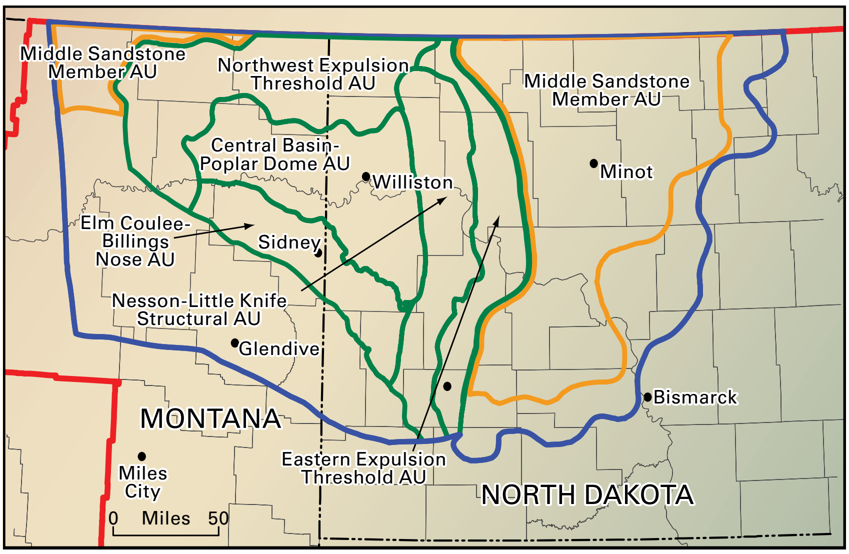
A mean resource of a conventional 4 million bbl was estimated for a hypothetical Middle Sandstone Member assessment unit on the play's northwest and eastern extremities.

Elm Coulee field in Montana, discovered in 2000, has produced about 65 million bbl of Bakken oil (OGJ, Dec. 11, 2006, p. 42).

The USGS worked with the North Dakota Geological Survey, a number of petroleum industry companies and

USGS BAKKEN ASSESSMENT UNITS

Fig. 1



Map showing boundary of Bakken-Lodgepole Total Petroleum System (TPS) in blue, five continuous assessment units in green, and one conventional assessment unit in orange defined for the assessment of undiscovered oil resources in the Upper Devonian-Lower Mississippian Bakken formation in the US portion of the TPS. The outermost green line defines the area of oil generation for the upper shale member of the formation.

independents, universities, and other experts to develop a geological understanding of the Bakken formation.

"The assessment of the Bakken formation indicates that most of the undiscovered oil resides within a continuous composite reservoir that is distributed across the entire area of the oil generation window and includes all members of the Bakken formation," the USGS said. That refers to the lower shale member, middle sandstone member, and upper shale member.

The upper and lower shale members of the Bakken formation are also the source for oil produced from reservoirs of the Mississippian Lodgepole formation.

"Most important to the Bakken-Lodgepole Total Petroleum System and the continuous assessment units within it are the geographic extent of the Bakken formation oil generation window, the occurrence and distribution of vertical and horizontal fractures, and the matrix porosity within the middle sandstone member," the USGS said.

The Bakken also underlies parts of Saskatchewan and Manitoba, but the USGS did not assess the Canadian portion of the basin.

Most active operators in the US Bakken play so far include Continental Resources Inc., Headington Oil Co., Lyco Energy Corp., EOG Resources Inc., ConocoPhillips, Marathon Oil Corp., Petro-Hunt Corp., Whiting Petroleum Corp., and Hess Corp. ✦

Appalachian basin's Devonian: more than a 'new Barnett shale'

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Recent reports on the successful development of Devonian organic shale reservoirs in southwestern Pennsylvanian and adjacent West Virginia have raised the speculation about this reservoir.

Both the nonindustry media and investment brokers and money managers have recently promoted the notion that the Appalachian Devonian is the "new Barnett Shale." The purpose of this article is to refute this claim and to explain why development of the Devonian holds potential beyond that seen in the highly successful Barnett shale.

Geologic setting

The Catskill Delta of the northern Appalachian basin is composed of a complex of predeltaic and deltaic sedimentary rocks of Devonian age.

Lower Devonian rocks are generally considered to be pre-Catskill Delta. They consist of interbedded limestone and sandstone reservoirs; the most famous of these reservoirs is the Oriskany formation. The Oriskany has gone through numerous phases of development and most recently has been developed for natural gas storage.

Traditionally, the Catskill Delta consists of Middle and Upper Devonian black shales. The stratigraphy of this interval is shown in Fig. 1 along with a location map that identifies the areas of interest in Pennsylvania and New York.

Part of the problem in evaluating the Devonian of the northern Appalachian basin is that many local names for the reservoirs have been imported from Ohio and West Virginia; this causes regional correlation to be confused.

Essentially, there were four pulses of deposition associated with the Catskill Delta (Table 1). Natural gas production is found in both the Middle and Upper Devonian. In previous papers, the author has described where production in New York is found. Van Tyne[1] provides a detailed discussion of the potential of Devonian reservoirs in New York.

CATSKILL DEPOSITION — Table 1

Deposition pulse	Geologic age
West Falls/Java	Upper Devonian
Sonyea	Upper Devonian
Genesee	Upper Devonian
Hamilton	Middle Devonian

CATSKILL PULSES — Table 2

Tectonic pulse	Pulse: Type	Pulse: Timing, ± million yr
Mesozoic Pangaea breakup	Extension	180
Appalachian event	Compression	300
Acadian event	Compression	350
Taconic event	Compression	400

Most recent developments in Pennsylvania (and West Virginia) involve the Marcellus member of the Hamilton Group. In these areas, erosion or nondeposition has caused much of the Upper Hamilton Group (or equivalent) to be lost; only the Marcellus member remains to be successfully developed.

The core of the Catskill Delta (and its Pennsylvania coequivalent) is found in the eastern third of the respective states. The members of each depositional pulse are thicker and more developed as one travels eastward, increasing the potential for source rock and reservoir horizons to form.

Recent work by Linsley[2] and others has suggested that there is a cyclical nature to each pulse of deposition (Fig. 2). Each general cycle includes organic shale overlain or interbedded with siltstones and sandstones; this coincides geologically with the types of sediments that should be found with an emerging delta.

It also suggests that sandstones and siltstones (with reservoir potential?) lie in proximity to organic shale source rock. This is dissimilar to the lithology and sedimentology of the Barnett shale. It implies that different reservoirs will be found in the Devonian of the Appalachian basin.

The author understands that the Barnett ranges from 200 to 800 ft thick at depths of 5,000 to 15,000 ft.[3] Both Upper and Middle Devonian rocks of the northern Appalachian Basin vary in thickness, depending especially upon location relative to the delta. Middle Devonian rocks can vary in thickness from 500 ft in along the western edge of deposition to 3,000 ft closer to the delta.

Depth to pay can range from less than 1,000 ft to more than 5,000 ft relative to the position of the delta. This implies that lower drilling costs for Devonian wells should be expected. Fracturing or artificial stimulation is necessary to produce the Barnett; special programs have been developed specifically to enhance production in this reservoir. Remote sensing studies completed by the author have identified four tectonic pulses that have created natural fracturing (Table 2). Each of these events caused tectonic stress that created secondary porosity and permeability in both source rock and reservoirs.

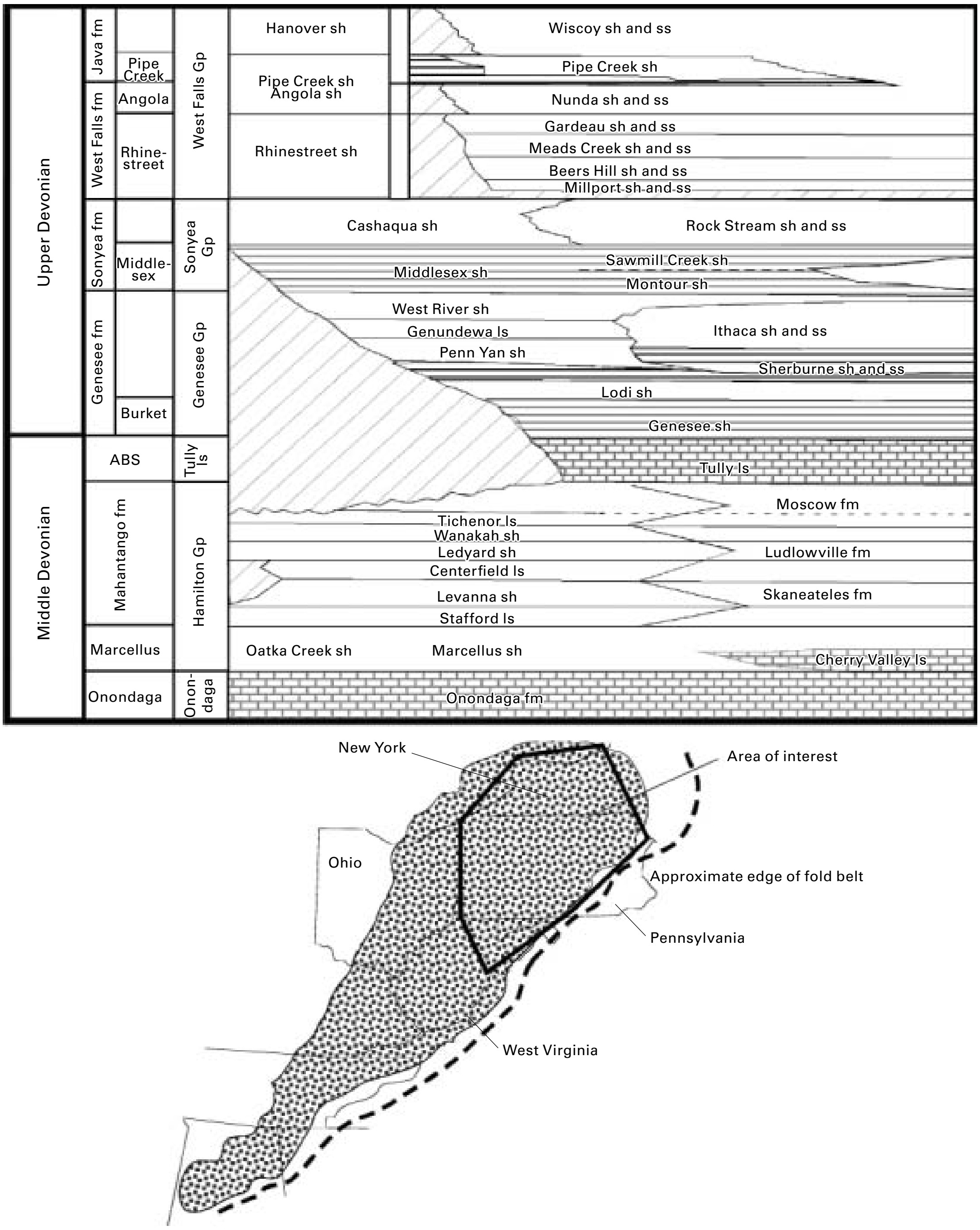
While the bulk of the compression/extension was located to the east of today's basin (i.e., the area of interest), it did enhance reservoir development and could aid recovery and reduce postdrilling engineering costs.

In addition to geologic and engineering conditions, there is one other important difference between the Barnett and the Devonian plays. The Barnett is one of a number of Midcontinent plays that supplies gas to a relatively limited marketplace.

The Devonian of the Appalachian basin, when fully developed, has the potential to supply gas to an area from Boston to Richmond. This represents

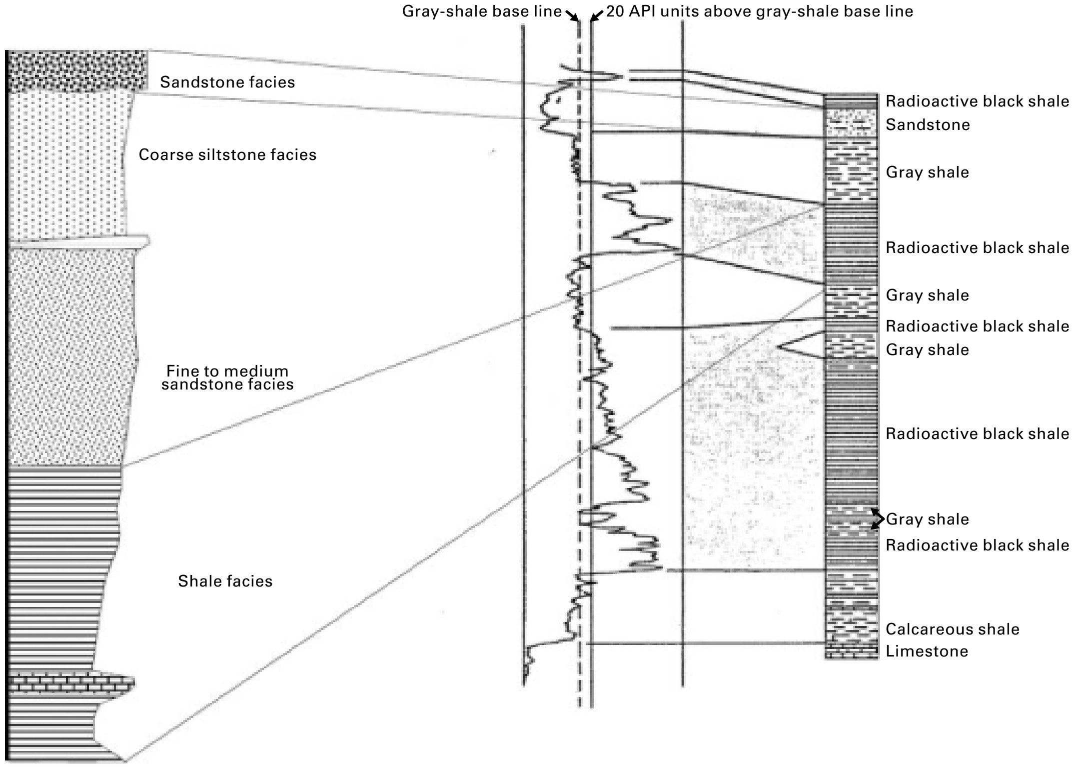
UPPER AND MIDDLE DEVONIAN STRATIGRAPHY FOR APPALACHIAN BASIN

Fig. 1



Depositional cycles in Devonian section, Appalachian basin

Fig. 2



Source: After Linsley, 1986.

From Van Tyne, 1983.

60% of the population of the US, and is generally speaking an area in which gas is not the primary choice for residential and industrial heating (i.e., there are plenty of marketing opportunities).

Further, when the resource is developed, New York gas will service New York City and its suburbs through intrastate pipelines that avoid FERC pricing and transportation charges. The same can be said for Pennsylvania gas distributed through eastern Pennsylvania. This suggests that traditional economic models based upon large volume reserves would not be applicable to this play.

Instead, lower volume long-lived reservoirs could be quite profitable. A number of producers in the northern Appalachian basin operate low volume wells that have been around for over 75 years, and they show profit above operating costs.

The relatively simplistic analogy of the Devonian shale being the "new Barnett" is wrong. This may be a promotion to encourage investment, but technically it is not true and in fact could be purposely misleading. The Devonian of the Appalachian basin is a complex geologic interval that hosts potential for the future.

Some analysts suggest that the Appalachian basin could hold in excess of 200 tcf of gas in place. Development of the reservoir will require astute geologic analysis, basin specific engineering, and the ability to create knowledge of the subsurface by drilling wells. There are no shortcuts here.

The reservoir potential is present, the infrastructure is in place, and the marketplace awaits success. In this author's opinion, the Devonian of the Appalachian basin isn't the new Barnett; it's better! ✦

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More US EOR projects start but EOR production continues decline

Guntis Moritis
Production Editor

Oil & Gas Journal's exclusive biennial enhanced oil recovery (EOR) survey, p. 47 shows that the number of EOR projects in the US has increased compared with the last survey taken 2 years ago. Although the current survey lists more projects, total production from all US EOR projects is less than in the last survey.

Production decline in California steam injection projects mostly accounts for the lower production, while new carbon dioxide floods mostly account for the increase in projects.

Outside of the US, the number of projects continues to increase, although operators for some of these projects did not update information listed in the previous survey (OGJ, Apr. 17, 2006, p. 37).

Survey description

OGJ published its first EOR survey in May 3, 1971, and the survey has been a biennial OGJ feature since 1974.

Tables A through E (pp. 47-59) list the projects in the 2008 EOR survey.

Projects listed are those that involve injecting fluids, other than water or methane, into a reservoir to improve or enhance oil recovery. Operators use the injectants during the initial production stage, after the primary depletion stage, or after the secondary production stage, which also is known as tertiary recovery.

The most common injectants include:

- Steam in heavy oil fields at shallower depths.
- Air for in situ combustion projects.
- Carbon dioxide in lighter oil fields.
- Hydrocarbon miscible gas in lighter oil fields.
- Chemicals and polymer in lighter oil fields.

Acid gas, a concentrated stream of hydrogen sulfide and carbon dioxide, is a new type of injectant seeing applications in EOR. Apache Canada Ltd. has a pilot in the Zama field in northwestern Alberta that produces about 1,000 bo/d.

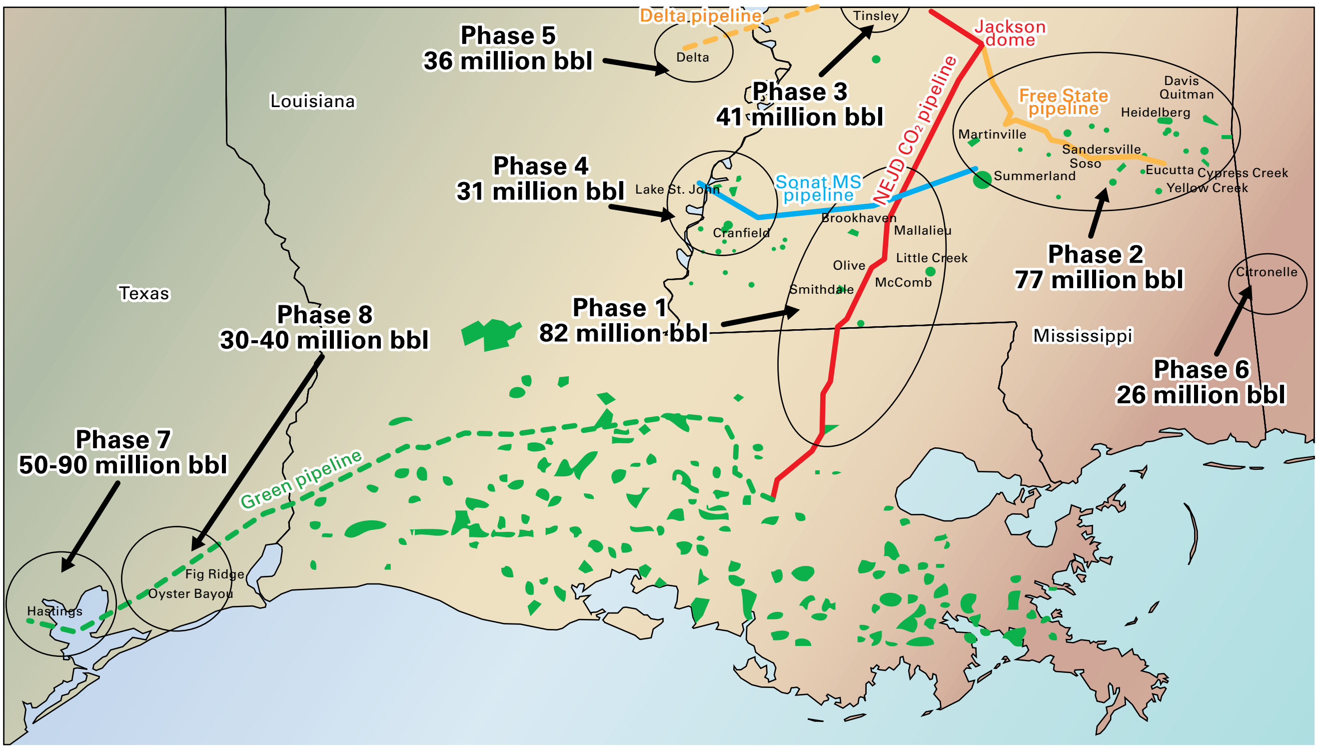
Chevron Corp. also injects sour gas as part of its second-generation project in the Tengiz field in Kazakhstan. A Chevron Mar. 13, 2008, presentation to analysts said that this expansion has increased production by 250,000 bo/d.

Petroleum Development Oman also has under development the $1 billion Harweel sour-gas injection project in southern Oman. PDO expects production for Phase 2AB of the project to produce about 60,000 bo/d by 2010, with a potential in the next decade of production increasing to 100,000 bo/d from the 10 fields in the cluster (OGJ, Nov. 5, 2007, p. 52).

About this report...
Every 2 years, the Oil & Gas Journal surveys worldwide projects that use various injection technologies to enhance oil recovery. Tables showing the projects surveyed start on p. 47, while the following pages describe events and trends affecting EOR activity levels.

DENBURY CO_2 PROJECT POTENTIAL

Fig. 1



Note: For Phases 7 and 8 the tertiary reserves are based on 10-17% recovery factors as of Dec. 31, 2006, estimates. Hastings field is under contract but not owned by Denbury.
Source: Denbury Resources Inc., The future in CO_2, January 2008.

US projects

OGJ's survey shows EOR contributing 643,000 b/d to US oil production (Tables 1 and 2), a 9,700-bo/d decrease from the 2006 survey. The production numbers represent the estimated production at the beginning of the year.

The survey includes 184 active projects, an increase of 32 compared with the 2006 survey.

Oil production decline in the mature thermal heavy-oil projects, mostly in California, is the main explanation for production decreasing. Production from US projects using thermal methods peaked in 1986 at 480,000 bo/d and has declined to the current 292,000 bo/d, or 12,000 bo/d less than shown in the 2006 survey.

Chevron Corp.'s operated Kern River field remains the largest single EOR project in the US, producing about 83,000 b/d, based on California Conservation Department statistics. Updated EOR statistics from Chevron were not available at press time.

Aera Energy LLC, a venture of ExxonMobil Corp. and Shell Inc., produces 95,000 bo/d from 17 projects, but this is a decrease from the 107,000 bo/d listed in the 2006 survey.

Oil production from in situ combustion has increased to 17,000 bo/d or 4,000 bo/d more than in the last survey. Encore Acquisition Co. has three projects while Continental Resources Inc. has 12 in fields in North and South Dakota as well as in Montana.

The combustion project with the most production is Continental Resources' Ceder Hill North Unit in Bowman County, ND. The company says the unit produces 11,500 bo/d or an increase of 3,400 bo/d from the last survey.

Thermal projects typically have long lives. For instance, the fire flood in Louisiana's Bellevue field started in 1970 and the field still produces 280 bo/d, while steam injection started in California's Belridge field, now operated by Aera, in 1961; the field currently produces 33,000 bo/d.

Steam injection projects outside of California also include a TXCO pilot in the Maverick basin of South Texas and MegaWest Energy's planned pilot in Vernon County, Mo.

In the US, the number of CO_2 miscible injection projects for enhancing oil recovery has increased (Table 1). The survey lists 100 ongoing projects compared with the 79 in the 2006 survey. Enhanced oil recovered from these projects also has increased to 240,000 b/d from the 235,000 b/d shown in the previous survey.

Units of Occidental Petroleum Corp. continue to add CO_2 projects. Oxy now operates 28 projects compared with 27 listed in the 2006 survey.

Denbury Resources Inc. also has added CO_2 floods. It now has 13 active floods compared with 7 listed in the previous survey. All of its CO_2 floods are in Mississippi except for one in Louisiana. Fig. 1 shows Denbury's existing

US EOR PRODUCTION

Table 1

	1986	1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008
Thermal												
Steam	468,692	455,484	444,137	454,009	415,801	419,349	439,010	417,675	365,717	340,253	286,668	273,947
Cumbustion in situ	10,272	6,525	6,090	4,702	2,520	4,485	4,760	2,781	2,384	1,901	13,260	17,025
Hot water	705	2,896	3,985	1,980	250	250	2,200	306	3,360	3,360	4,370	1,776
Total thermal	**479,669**	**464,905**	**454,212**	**460,691**	**418,571**	**424,084**	**445,970**	**417,675**	**371,461**	**345,514**	**304,298**	**292,748**
Chemical												
Micellar-polymer	1,403	1,509	617	254	64	0	0	0				
Polymer	15,313	20,992	11,219	1,940	1,828	139	139	1,598				
Caustic/alkaline	185											
Surfactant			20					60	60	60		
Total chemical	**16,901**	**22,501**	**11,856**	**2,194**	**1,892**	**139**	**139**	**1,658**	**60**	**60**	**0**	**0**
Gas												
Hydrocarbon miscible/ immiscible	33,767	25,935	55,386	113,072	99,693	96,263	102,053	124,500	95,300	97,300	95,800	81,000
CO_2 miscible	28,440	64,192	95,591	144,973	161,486	170,715	179,024	189,493	187,410	205,775	235,344	240,313
CO_2 immiscible	1,349	420	95	95				66	66	102	2,698	9,350
Nitrogen	18,510	19,050	22,260	22,580	23,050	28,017	28,117	14,700	14,700	14,700	14,700	19,700
Flue gas (miscible and immiscible)	26,150	21,400	17,300	11,000	—	—	—	—				
Other				6,300	4,400	4,350	4,350	—				
Total gas	**108,216**	**130,997**	**190,632**	**298,020**	**288,629**	**299,345**	**313,544**	**328,759**	**297,476**	**317,877**	**348,542**	**350,363**
Other												
Carbonated waterflood												
Microbial				2	2							
Total other			**2**	**2**								
Grand total	**604,786**	**618,403**	**656,700**	**760,907**	**709,094**	**723,568**	**759,653**	**748,092**	**668,997**	**663,451**	**652,840**	**643,111**

ACTIVE US EOR PROJECTS

Table 2

	1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008
Thermal											
Steam	133	137	119	109	105	92	86	55	46	40	45
Cumbustion in situ	9	8	8	5	8	7	5	6	7	12	12
Hot water	10	9	6	2	2	1	1	4	3	3	3
Total thermal	**152**	**154**	**133**	**116**	**115**	**100**	**92**	**65**	**56**	**55**	**60**
Chemical											
Micellar-polymer	9	5	3	2							
Polymer	111	42	44	27	11	10	10	4	4	0	1
Caustic/alkaline	4	2	2	1	1	1					
Surfactant		1									1
Total chemical	**124**	**50**	**49**	**30**	**12**	**11**	**10**	**4**	**4**	**0**	**2**
Gas											
Hydrocarbon miscible/ immiscible	22	23	25	15	14	11	6	7	8	13	13
CO_2 miscible	49	52	52	54	60	66	63	66	70	79	100
CO_2 immiscible	8	4	2	1	1		1	1	1	2	5
Nitrogen	9	9	7	8	9	10	4	4	4	3	4
Flue gas (miscible and immiscible)	2	3	2								
Other			1	1							
Total gas	**90**	**91**	**89**	**79**	**84**	**87**	**74**	**78**	**83**	**97**	**122**
Other											
Microbial			2	1	1	1					
Total other	**0**	**0**	**2**	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**0**
Grand total	**366**	**295**	**273**	**226**	**212**	**199**	**176**	**147**	**143**	**152**	**184**

and planned fields.

Oxy's Wasson Denver Unit is the field with the most CO_2 EOR production, producing 26,850 bo/d. CO_2 injection in the field started in 1983.

Most US hydrocarbon miscible projects are on the North Slope of Alaska with the largest in the Prudhoe Bay and Kuparuk River fields.

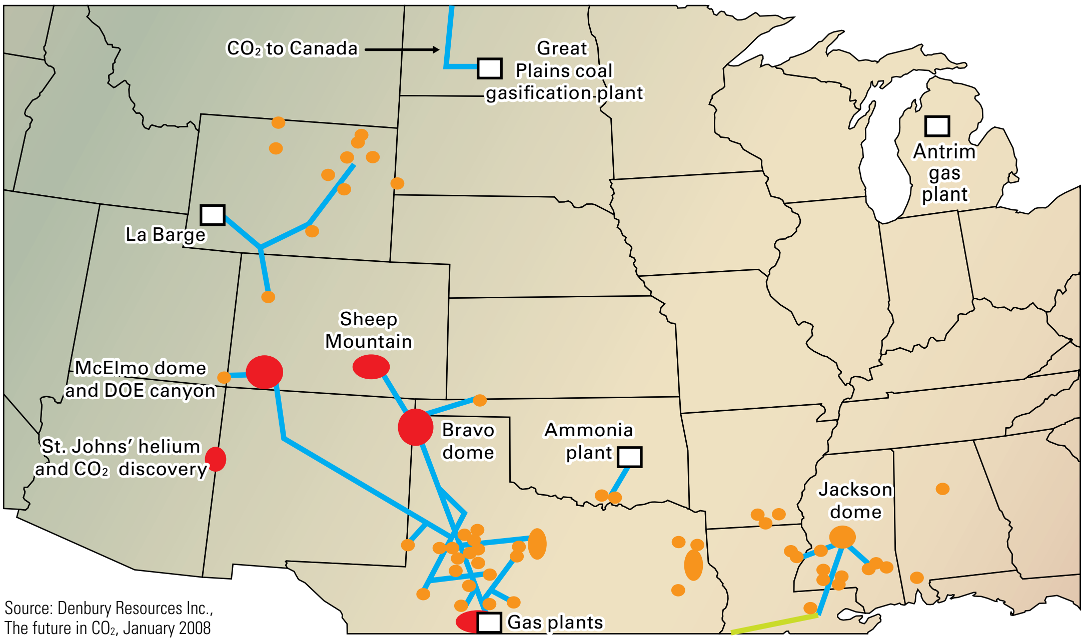
The survey does not include any US EOR projects that involve injecting surfactants, polymers, or other chemicals. These projects tend to be smaller and with shorter lives, and operators chose not to respond to the survey.

One recent announcement on a chemical flood is Rex Energy's plan for starting two alkali-surfactant-polymer (ASP) pilots in an old oil field in the Illinois basin in second-quarter 2008. (OGJ, Feb. 11, 2008, p. 39).

The pilots will be on 1-acre spacing in Lawrence field, near Bridgeport, Ill. Lawrence field, discovered in 1906, still

Current CO_2 sources

Fig. 2



Source: Denbury Resources Inc., The future in CO_2, January 2008

oil field in the basin and for some other targeted fields.

If both company's meet their obligations, EOR Inc. expects the pipeline to be built by late 2010.

Denbury has plans to increase its CO_2 pipeline, with one possible line transporting CO_2 into East Texas. The company also has signed CO_2 purchase contracts with three planned chemical plants. In a January presentation, Denbury said, contingent on the plants being built, it expects to obtain:

- 190-225 MMcfd from the Faustina petroleum coke gasification plant, Donaldsonville, La., starting in 2010.
- 190-225 MMcfd from the US-TransCarbon gasification plant, Beaumont, Tex., starting in 2011.
- 350-400 MMcfd from the Rentech gasification plant, Natchez, Miss., starting in 2011-12.

In Wyoming, Anadarko Corp. has plans to extend to the Linch-Sussex area its 125-mile pipeline that currently transports CO_2 to the Salt Creek and Monell fields. The La Barge gas plant is the source for this CO_2.

produces about 1,800 bo/d from 1,000 wells and Rex Energy says initial oil in place in the field, the largest in the Illinois basin, was an estimated 1 billion bbl of which about 400 million bbl has been produced

Another chemical flood is Cano Petroleum Inc. alkaline-surfactant-polymer pilot consisting of four wells on 2.5 acres in the Nowata field. ASP injection started toward the end of 2007 and Cano expects incremental oil production in 2008.

CO_2 availability

Availability of CO_2 limits industry's ability to expand CO_2 EOR flooding in the US (Fig. 2). Charles Fox, vice-president of Kinder Morgan Carbon Dioxide Co., told OGJ that the company had completed its DOE canyon gas plant in southwestern Colorado in early 2008, thereby adding 107 MMcfd of CO_2 availability to the Permian basin of West Texas and New Mexico. He added that expansion in McElmo dome, also in Colorado, by mid-2008 will add another 200 MMcfd of CO_2 production capacity. The addition CO_2 form McElmo dome and DOE canyon has been already sold to existing projects and to the North Ward Estes EOR project, which is the anchor field for deliveries from DOE canyon, Fox said.

In 2007, Fox noted that the average amount of CO_2 deliveries to the Permian basin was 1.371 bcf/day, broken down as 966 MMcfd from McElmo dome, 290 MMcfd from Bravo dome, 40 MMcfd from Sheep Mountain, and 75 MMcfd from Val Verde gas plants. These deliveries were slightly less than the 1.388 bcf/day delivered in 2006. Fox explains that the lower deliveries were due to an imbalance in demand and supply during summer 2007. He expects CO_2 deliveries to the Permian basin during 2008 will set a record.

Enhanced Oil Resources Inc. recently announce a memorandum of understanding (MOU) for developing a pipeline with SunCoast Energy Corp. to carry CO_2 350 miles from its St. Johns, Ariz., helium and CO_2 field to the Permian basin. The company's initial plans are to transport 350 MMcfd of CO_2 into the Permian basin. The pipeline design capacity will be 500 MMcfd.

EOR Inc. has reserved the right to the first 175 MMcfd of capacity for its own

Canadian EOR

Expansion of in situ production through steam-assisted gravity drainage (SAGD) and cyclic-steam projects continues at a rapid pace. Responses to the survey from some companies along with information from an Alberta Employment, Immigration, and Industry, December 2007 report indicate that the following projects were producing:

- ConocoPhillips Canada began producing from Phase 1 of its Surmont

SAGD project in 2007 with a designed capacity of producing 25,000 bo/d.

• Devon Energy Corp. completed construction of its Jackfish Phase 1 SAGD project with first steaming starting in the third quarter of 2007.

• Connacher Oil & Gas Corp. completed construction at Pod 1 of its Great Divide SAGD Project. Production started in the fourth quarter of 2007 and the company expects to reach 10,000 bo/d in late 2008.

• Petro-Canada production averaged 22,000 bo/d during third quarter 2007 at its MacKay River in situ project.

• EnCana Energy Corp.'s in situ SAGD Christina Lake project produces about 6,000 bo/d and its SAGD Foster Creek project produced 52,000 bo/d.

• Japan Canada Oil Sands (JACOS) SAGD Hangingstone pilot produces an average 8,000-8,500 bo/d.

• Total E&P Canada Ltd. started SAGD production from its Joslyn project in November 2006 and targets 10,000 b/d for 2008.

• Shell Canada Energy Ltd. started production from its Orion SAGD project at yearend 2007. Designed capacity is 10,000 bo/d.

• Canadian Natural Resources Ltd. is producing 70,000 b/d from its Primrose in situ cyclic steam project.

• Husky Energy started producing at its Tucker SAGD project, designed for 30,000 bo/d.

• Shell Canada Energy Ltd.'s Peace River projects produced 18,000 bo/d at yearend 2007.

• Suncor Energy Inc.'s Firebag SAGD was producing at about 29,000 bo/d.

• The largest steam project remains Imperial Oil Ltd's. Cold Lake, averaging about 154,000 bo/d in 2007.

Other countries

Chevron Corp.'s operated Duri field on Sumatra Island in Indonesia remains the largest single EOR project in the world, producing about 190,000 bo/d.

In 2007, Chevron announced the start of surfactant-polymer pilot in Minas field, the largest field in Indonesia, with about 4 billion bbl of oil initially in place. The company expects to start chemical injection in early 2011 and expects results in 2012.

Chevron also has under construction the North Duri steamflood that will start producing in 2008 and is expected to attain 70,000 bo/d of production.

Another steamflood Chevron has under construction is in the Neutral Zone between Suadi Arabia and Kuwait. Production started in 2007 and Chevron expects production to reach 10,000 bo/d in 2008.

Other countries with active EOR projects include China and Venezuela, although the operators did not update the statistics for these projects.

Petroleos Mexicanos had good success in increasing oil production with nitrogen injection in the offshore Cantarell field , where oil production increased to more than 2 million b/d in 2004 from the 1 million b/d in 1996. Currently Cantarell produces about 1.8 million b/d.

Pemex also has started nitrogen injection in the Ku-Maloob-Zapp, and Jujo Tecominoacan fields.

Bankers Petroleum Ltd. began a steam injection pilot in the Patos Marinza in Albania. The Company expects to drill eight new wells in its thermal steam project in the fourth quarter of 2008.

Petroleum Development Oman besides its Harweel sour-gas injection project, in 2007 started injected steam in the Amal West field pilot (OGJ, Nov. 5, 2007, pp. 56-65). In 2008, it has plans to start steam injection pilots in Amal East and Thayfut fields in 2008. Other PDO EOR projects under construction are steam projects in Qarn Alam and Fahud fields, as wells as a polymer flood in Marmul field. It expects Qarn Alam to come on stream in 2010 and produce about 30,000 bo/d and to start in 2008 steam injection in Fahud and polymer injection in Marmul. In Oman, Occidental is also developing the Mukhalza steam injection project. ✦

Guide to EOR tables

- **A.** Planned EOR projects
- **B.** Producing thermal EOR in US
- **C.** Producing CO_2, other gas, and chemical EOR in US
- **D.** Producing Canadian EOR projects
- **E.** Producing EOR outside of US and Canada

Abbreviations

Formation type	Previous production	Project maturity	Project evaluation	Project scope
S: Sandstone	Prim: Primary	JS: Just started	TETT: Too early to tell	P: Pilot project
LS: Limestone	WF: Waterflood	HF: Half finished	Prom.: Promising	FW: Field-wide
Dolo: Dolomite	GI: Gas injection	NC: Nearing completion	Succ.: Successful	LW: Lease-wide
Congl.: Conglomerate	C: Cyclic steam	C: Completed	Disc.: Discouraging	RW: Reservoir-wide
Tripol: Tripolite	HW: Hot water	PP: Postponed	None: Not evaluated	Exp. L: Expansion likely
US: Unconsolidated sand	SS: Steam soak	Term.: Terminated		Exp. UL: Expansion unlikely
	S: Steam	Del: Deleted		
	SD: Steam drive	TS: Temporarily suspended		
	SF: Steam flood			
	HC: Hydrocarbon			

2008 worldwide EOR survey

Leena Koottungal
Survey Editor

Planned projects — Table A

Type and operator	Field	Location	Pay zone	Size, acres	Depth, ft	Gravity, °API	Start date
CO_2 immiscible							
Anadarko	Sussex	Johnson Co., Wyo.	Tensleep	2,544	9,000	29	2010
ARC Energy Trust	Redwater	Redwater, Alta., T58 R21 W4M	Leduc D-3	160	3,000	36	7/08
Denbury	Cranfield	Adams Co., Miss.	Lower Tuscaloosa	7,754	10,250	39	5/08
Denbury	Heidelberg West	Jones & Jasper Co., Miss.	Eutaw	915	5,000	22	10/08
CO_2 miscible							
Core Energy	Chester 6	Otsego, Mich.	A1 Carbonate	100	5,700	43	6/09
Core Energy	Niagaran "A"	Otsego, Mich.	Brown Niagaran	120	5,700	43	12/09
Core Energy	Niagaran "B"	Otsego, Mich.	Brown Niagaran	140	5,700	43	12/10
Denbury	Delhi	Richland, Madison, Franklin parishes, La.	Holt-Bryant	8,000	3,300	42	1/09
Denbury	W. Lazy Creek	Pike Co., Miss.	Lower Tuscaloosa	600	10,250	39	10/09
Fasken	Abell	Crane Co., Tex., Blk 1C, H&TC RR Survey	Devonian	769	5,200	40	1/09
Fasken	River Bend	Crane Co., Tex., Blk 1C, H&TC RR Survey	Devonian	470	5,300	40	1/09
Fasken	Hanford ROZ	Gaines, Tex.	San Andres	340	5,700	32	1/09
Kinder Morgan	Katz	Stonewall Co., Tex.	Strawn	5,483	4,800	40	5/09
Occidental	North Dollarhide	Andrews Co., Tex.	Clearfork	270	6,500	40	2008
Petrobras	Miranga	Brazil onshore	Taquipe	1,230	3,940	33	2008
Ridgeway Arizona Oil	Milnesand	Roosevelt Co., NM	San Andres	40	4,600	27	2008
Steam							
Carrizo	Camp Hill	Anderson Co., Tex	Carrizo	800	500	19	2008
Derek Oil & Gas Corp.	Newcastle	Weston Co., Wyo.	Newcastle	300	800	20	9/08
MegaWest	Marmaton River	Vernon, Calif.	Warner	10	250	15	2008
Nederlandse Aardolie Maatschappij (NAM)	Schoonebeek	Drenthe, Netherlands	Bentheim	4,000	2,600	25	2010
Shell Canada	Orion	Cold Lake, Alta., Township 64 Range 3 West of 4th	Clearwater	5,120	1,350	10	
Shell Canada	Peace River	Peace River Township 84 R18W5	Bluesky	16,340	1,800	8	
Wintershall	Emlichheim, Block 8/9 North	Germany, Lower Saxony, Grafschaft Bentheim	Valanginian	37	2,500-2,700	25	7/08
Polymer							
CNRL	Horsefly Lake	Alberta	Mannville	4,500	2,500	22	2009
Petrobras	Voador	Brazil offshore	Marlim	740	8,000	21	2009
Tecpetrol	El Tordillo	Chubut, Comodoro Rivadavia, Argentina	CR	848	5,500	21	8/08
Tecpetrol	El Tordillo	Chubut, Comodoro Rivadavia, Argentina	CR	164	5,500	21	2/08
Tecpetrol	El Tordillo	Chubut, Comodoro Rivadavia, Argentina	CR	82	5,500	21	12/09
Wintershall	Bockstedt	Lower Saxony, Germany	Valanginian	1	3,600-4,300	24	2010
Combustion							
Petrobras	Rio Preto Oeste	Brazil onshore	Mucuri	1,045	3,380	17	2009
Surfactant-Polymer							
Occidental	Midland Farms Unit	Andrews Co., Tex.	Grayburg	4,000	4,800	34	2010
Rex Energy	Lawrence	Lawrence Co., Tex.	Cypress, Bridgeport	2	800-1,400	36-40	2009

PRODUCING THERMAL EOR IN US

Type and operator	Field	State	County	Start date	Area, acres	No. wells prod.	No. wells inj.	Pay zone	Forma-tion	Poros-ity, %
Steam										
Aera Energy	South Belridge	Calif.	Kern	1961	6,200	2,200	1,000	Tulare	US	35
Aera Energy	South Belridge	Calif.	Kern	1995	60	163	62	Diatomite Opal A	Tripol	60
Aera Energy	Coalinga	Calif.	Fresno	1965	574	376	68	Temblor	S	32
Aera Energy	Coalinga	Calif.	Fresno	1987	290	95	20	Etchegoin	S	34
Aera Energy	Cymric	Calif.	Kern	12/86	600	162	147	Tulare	S	36
Aera Energy	Lost Hills	Calif.	Kern	8/77	100	246	86	Etchegoin	US	40
Aera Energy	Lost Hills	Calif.	Kern	11/75	170	256	94	Tulare	US	40
Aera Energy	McKittrick	Calif.	Kern	3/88	160	118	116	Tulare	S	36
Aera Energy	Midway-Sunset	Calif.	Kern	11/67	1,600	1,749	167	Potter	S	30
Aera Energy	Midway-Sunset	Calif.	Kern	10/70	1,230	1,440	280	Monarch	S	25-32
Aera Energy	Midway-Sunset	Calif.	Kern	1984	15	3	0	Sub Lakeview	S	30
Aera Energy	Midway-Sunset	Calif.	Kern	1969	50	75	16	Metson	S	30
Aera Energy	Midway-Sunset	Calif.	Kern	1988	66	98	19	Marvic	S	30
Aera Energy	Midway-Sunset	Calif.	Kern	1980	152	170	1	Tulare	S	31
Aera Energy	Midway-Sunset Diatomite	Calif.	Kern	1997	48	38	0	Diatomite		65
Aera Energy	San Ardo	Calif.	Monterey	6/68	125	38	0	Aurignac	S	34.5
Aera Energy	San Ardo	Calif.	Monterey	3/80	546	170	49	Lombardi	S	32.5
Berry	Midway-Sunset	Calif.	Kern	11/02	15	35	20	Tulare	S	30
Berry	North Midway-Sunset	Calif.	Kern	1965	160	125		Potter	S	30
Berry	South Midway-Sunset	Calif.	Kern	1964	600	1,200		Monarch	S	30
Berry	Placerita	Calif.	Los Angeles	1987	120	50	58	Lower Kraft	S	27
Berry	Midway-Sunset South	Calif.	Kern	2005	40	50	4	Main 10-10	S	30
Berry	Poso Creek	Calif.	Kern	2005	200	77	3	Etchegoin/Chanac	S	33
Berry	North Midway-Sunset	Calif.	Kern	2006	100	87	0	Diatomite	Tripol.	65
Berry	Midway-Sunset South	Calif.	Kern	2007	10	4	0	Diatomite	Tripol.	65
Berry	Midway-Sunset South	Calif.	Kern	2007	60	10	1	Monarch	S	30
Chevron	Cymric 1Y	Calif.	Kern	1/80	380	510	0	Antelope		58
Chevron	Cymric	Calif.	Kern	5/75	552	360	80	Tulare	S	34.8
Chevron	Midway	Calif.	Kern	1964	1,214	2,039	225	Potter	US	30
Chevron	Midway	Calif.	Kern	1982	80	123	3	Tulare	US	31
Chevron	Midway	Calif.	Kern	1970	1,200	711	69	Spellacy	US	30
Chevron	West Coalinga	Calif.	Fresno	6/90	1,291	541	132	Temblor	S	34
Chevron	Kern River	Calif.	Kern	9/68	9,660	8,692	1,219	Kern River	S	32
Chevron	San Ardo	Calif.	Monterey	7/87	125	92	13	Lombardi	S	34
Derek Oil & Gas Corp.	LAK Ranch	Wyo.	Newcastle	4/04	20	1	3	Newcastle	S	22
Derek Oil & Gas Corp.	Newcastle	Wyo.	Weston	3/07	30	8	4	Newcastle Sandstone	S	22
ExxonMobil	South Belridge	Calif.	Kern	12/87	90	48	24	Tulare	S	38
Ivanhoe Energy	Midway-Sunset South	Calif.	Kern	9/01	90	45	40	Antelope	S	34
Ivanhoe Energy	Midway-Sunset South	Calif.	Kern	6/02	94	17	17	Antelope	S	34
Naftex	Edison 27-RT	Calif.	Kern	7/77	30	65	29	Chanac	S	30
Occidental	Kern Front	Calif.	Kern	1981	3,380	580	70	Etchegoin & Chanac	SS	30
Occidental	North Antelope Hills	Calif.	Kern	1980	300	44	2	Packwood & Point of Rocks	SS	35
Seneca Resources	Midway-Sunset	Calif.	Kern	1968	320	800	0	Potter Sand	US	37
Stockdale	Kern Front	Calif.	Kern	2/93	160	54	6	Etchegoin	S	30
Tidelands	Wilmington (Parcel A)	Calif.	Los Angeles	6/96	44	3	2	S Tar	US	31
Hot water										
Carrizo	Camp Hill	Tex.	Anderson	1994	37	54	25	Carrizo	S	37
Chevron	San Ardo	Calif.	Monterey	7/87	700	7	3	Aurignac	S	32
Chevron	West Coalinga	Calif.	Fresno	5/73	780	194	180	Temblor	S	34
Combustion										
Bayou State	Bellevue	La.	Bossier	1970	200	90	15	Nacatoch	S	32
Continental Resources	Medicine Pole Hills Unit	ND	Bowman	1985	8,960	15	9	Red River B & C	Dolo.	17
Continental Resources	West Medicine Pole Hills Unit	ND	Bowman	2001	14,335	18	12	Red River B & C	Dolo.	17
Continental Resources	Cedar Hills North Unit	ND	Bowman	2002	51,200	125	77	Red River B	Dolo.	18
Continental Resources	Buffalo	SD	Harding	1979	7,680	18	5	Red River B	Dolo.	20
Continental Resources	West Buffalo	SD	Harding	1987	4,640	11	5	Red River B	Dolo.	20
Continental Resources	South Buffalo	SD	Harding	1983	20,800	37	12	Red River B	Dolo.	20
Continental Resources	West Cedar Hills Unit	Mont.	Fallon	2003	7,800	12	5	Red River B	Dolo.	17
Continental Resources	South Medicine Pole Hills Unit	ND	Bowman	2003	11,500	10	6	Red River B	Dolo.	17
Encore Acquisition	Pennel Phase 1	Mont.	Fallon	2002	2,924	22	8	Red River A	Dolo.	17
Encore Acquisition	Pennel Phase 2	Mont.	Fallon	2002	10,010	56	24	Red River A	Dolo.	17
Encore Acquisition	Little Beaver	Mont.	Fallon	2002	10,400	57	29	Red River A & B	Dolo.	17

TABLE B

Perme-ability, md	Depth, ft	Gravity, °API	Oil, cp	Oil, °F.	Prev. prod.	Satur. % start	Satur. % end	Proj. matur.	Tot. prod., b/d	Enh. prod., b/d	Proj. eval.	Profit	Project scope
1,000-3,000	300-1,400	13-14	1,500-4,000	95	Prim.	75	20	NC	33,000	33,000	Succ.	Yes	FW
1-5	1,000-1,800	28-30	2-50	110	WF	45	20	JS	5,000	1,500	Prom.	Yes	P
200-2,500	825-1,650	12-13	2,000-10,000	84-98	Prim.	60	10	HF	4,611	4,611	Succ.	Yes	FW
800-1,000	650-1,000	9-10	11,500-28,000	84	Prim.	55	10	HF	1,692	1,692	Succ.	Yes	FW
1,000-3,000	1,000	11-14	1,000-2,000	95-105	Prim.	65	20	NC	3,500	3,500	Succ.	Yes	FW
800-1,500	350	14	1,500-4,000	95	Prim.	55	20	HF	2,200	2,200	Succ.	Yes	FW
1,000-3,000	200	13	1,500-4,000	82	Prim.	60	20	HF	3,200	3,200	Succ.	Yes	FW
1,000-2,000	600	10-12	13,000-51,000	83	Prim.	60	20	HF	2,000	2,000	Succ.	Yes	FW
1,000-4,000	500-1,500	12		91-110	Prim.	60-75	15	HF	14,794	14,794	Succ.	Yes	FW
700-4,000	800-1,500	13	1,500-5,000	85-100	Prim.	50-75	15	HF	17,850	17,850	Succ.	Yes	FW
4,500	1,300	13	4,000	90	Prim.	60	15	NC	5	5	Succ.	Yes	LW
3,000	1,100	11	10,000	130	Prim.	75	15	HF	1,108	1,108	Succ.	Yes	LW
300	1,100	13	3,500	104	SS	65	15	HF	1,138	1,138	Succ.	Yes	LW
300-6,000	1,000	11-14	6,000	90	Prim.	60	16	HF	1,230	1,230	Succ.	Yes	FW
5	0-1,100	12.5	1,000	90	Prim.	75		HF	190	190	Succ.	Yes	LW
2,000	2,300	12	1,000	130	SS	55	27	NC	496	496	Succ.	Yes	FW
2,260	2,100	11	3,000	125	SS	55	27	HF	6,285	6,285	Succ.	Yes	FW
3,500	800	10	10,000	90	CS	60	23	JS	1,000	750	Succ.	Yes	RW
3,000	1,300	14	4,000	85	Prim.	70	15	NC	550	400	Succ.	Yes	FW
2,000	1,000	13	8,000	80	Prim.	70	15	HF	10,000	7,000	Succ.	Yes	FW
1,500	1,800	13	10,000	90	Prim./Cyclic	60		HF	3,000	2,700	Succ.	Yes	FW, RW, Exp. L
1,500	1,700	13	8,000	80	Prim./Cyclic	60		JS	400	300	TETT		RW
4,000	1,200	13	2,800	110	Cyclic	50		JS	700	650	Prom.		FW
1	800	14			SD	65		JS	1,530	1,530	Prom	TETT	Exp. L, LW
1	1,100	14	4,000	90		60		JS		25	TETT	TETT	Exp. L, LW
800	1,400	14	4,000	90	C	65		JS		200	TETT	TETT	Exp. L, LW
5	1,500	13		110	Prim.	20-60		NC	21,200	21,200	Succ.	Yes	LW
2,700	1,200	12	5,200	100	SS	53	18	HF	10,200	10,200	Succ.	Yes	LW
3,000	1,500	12	4,000	100	C	60	15	HF	21,000	21,000	Succ.	Yes	FW
1,300	1,500	11	5,000	100	Prim.	50	43	HF	500	500	Succ.	Yes	Exp. L
2,250	1,500	12	5,000	100	Prim.	60	20	HF	9,400	9,400	Succ.	Yes	Exp. L
1,510	1,640	14	3,720	100	SS	44	14	HF	6,558	6,558	Succ.	Yes	RW
2,000	1,000	13	4,000	90	Prim.	50	15	HF	86,000	86,000	Succ.	Yes	FW
6,700	1,900	12	1,200	135	C	46	15	HF	2,750	2,750	Succ.	Yes	P (Exp. L)
100	1,000	16	20	54	NA	85	60	JS	40	40	TETT	TETT	P
100	800	20	20	54	SD	85	60	C	30	30	Prom.		P
2,000	1,250	13	450	95				HF	1,000	800	Succ.	Yes	FW
200-1,500	900-1,400	15-16	345	100	Prim.	80	60	NC	360	345	Succ.	Yes	FW
500-2,000	450	11	20,000	80	NA	85	60	JS	200	200	TETT	TETT	P (Exp. L)
2,800	1,000	14	2,000	90	Prim.	50	15	NC	550	550	Succ.	Yes	FW
2,000	1,800	14.8	1,525	95	Prim.	45	15	HF	4,000	3,500	Succ.	Yes	FW
2,500	1,200	13	2,000	80	Prim.	50	35	HF	160	120	Succ.	Yes	FW
1,000-10,000	1,100-1,700	12	3,000	100	Prim.	65	20	HF	6,000	4,500	Succ.		RW
1,000	2,000	13		80	SS	70		JS	700	550	Succ.	Yes	Exp. L
1,000	2,300	13	300	125	WF	58	28	JS	350	350	Succ.		P
3,500	450-500	19	1,200	75	Prim.	65	29	HF	125	100	Succ.		LW
2,000	2,100	12	900	135	SF	15	10	NC	253	226	Succ.	Yes	LW
1,500	1,350	14	3,350	100	SS	48	15		1,450	1,450	Succ.	Yes	RW
650	400	19	660		Prim.	94	49	HF	240	240	Succ.	Yes	FW
15	9,500	38	2	230	Prim.	52	30	HF	350	350	Succ.	Yes	FW
10	9,500	33	2	215	Prim.	50	33	JS	900	900	Succ.	Yes	FW
10	9,000	33	2	215	Prim.	55	26	JS	11,500	11,500	Succ.	Yes	FW
10	8,450	31	2	215	Prim.	55	20	NC	525	525	Succ.	Yes	FW
10	8,450	32	2	215	Prim.	55	20	HF	425	425	Succ.	Yes	FW
10	8,450	31	2	215	Prim.	55	20	HF	975	975	Succ.	Yes	FW
10	9,000	33	2	215	Prim.	55	26	JS	725	725	Succ.	Yes	FW
10	9,200	33	2	220	Prim.	50	30	JS	375	375	Prom.		FW
10	8,800	33	1.44	200	WF	75	39	JS	429	160	Succ.	Yes	Exp. L
10	8,800	33	1.44	200	WF	85	46	JS	1,550	100	Prom.	Yes	Exp. L
10	8,300	33	1.44	200	WF	83	60	JS	1,650	750	Prom.	Yes	Exp. L

PRODUCING CO_2, OTHER GAS, AND CHEMICAL EOR IN US

Type and operator	Field	State	County	Start date	Area, acres	No. wells prod.	No. wells inj.	Pay zone	Formation	Porosity, %
CO_2 miscible										
Anadarko	Patrick Draw Monell	Wyo.	Sweetwater	9/03	3,500	56	47	Mesaverde Almond	S	20
Anadarko	Salt Creek	Wyo.	Natrona	1/04	3,500	174	153	Wall Creek 2 (Frontier)	S	18
Anadarko	Salt Creek	Wyo.	Natrona	5/07	5	1	1	Wall Creek 1 (Frontier)	S	17
Anadarko	Sussex	Wyo.	Johnson	12/04	25	4	1	Tensleep	S	10
Apache	Slaughter	Tex.	Hockley & Terry	5/85	569	24	11	San Andres	Dolo.	12.5
Apache	Slaughter	Tex.	Hockley & Cochran	6/89	8,559	228	154	San Andres	Dolo.	10
Chaparral Energy	Sho-Vel-Tum	Okla.	Stephens	9/82	1,100	60	40	Sims	S	16
Chaparral Energy	Camrick	Okla.	Beaver	4/01	2,320	32	19	Morrow	S	15
Chaparral Energy	North Perryton	Tex.	Ochiltree	12/07	2,500	6	3	Upper Morrow	S	15.2
Chevron	Rangely Weber Sand	Colo.	Rio Blanco	10/86	18,000	378	262	Weber SS	S	12
Chevron	Mabee	Tex.	Andrews-Martin	1/92	3,600	220	85	San Andres	Dolo.	9
Chevron	Slaughter Sundown	Tex.	Hockley Co	1/94	5,500	155	144	San Andres	Dolo.	11
Chevron	Vacuum	NM	Lea Co.	7/97	1,084	48	24	San Andres	Dolo.	12
ConocoPhillips	South Cowden	Tex.	Lea	2/81	4,900	43	22	San Andres	Dolo.	11.7
ConocoPhillips	Vacuum	NM	Lea	2/81	4,900	192	103	San Andres	Dolo.	11.7
Core Energy	Charlton 6	Mich.	Otsego	2006	60	1	1	Silurian-A1/Niagaran	LS/Dolo.	
Core Energy	Charlton 30-31	Mich.	Otsego	2005	285	2	1	Silurian-A1/Niagaran	LS/Dolo.	
Core Energy	Dover 33	Mich.	Otsego	1996	120	2	1	Silurian-Niagaran	LS/Dolo.	7
Core Energy	Dover 33	Mich.	Otsego	1996	85	2	1	Silurian-A1/Niagaran	LS/Dolo.	5
Core Energy	Dover 35	Mich.	Otsego	2004	80	2	2	Silurian-Niagaran	LS/Dolo.	7
Core Energy	Dover 35	Mich.	Otsego	2004	70	3	2	Silurian-A1/Niagaran	LS/Dolo.	5
Core Energy	Dover 36	Mich.	Otsego	1997	200	1	2	Silurian-Niagaran	LS/Dolo.	7
Core Energy	Dover 36	Mich.	Otsego	1997	190	1	2	Silurian-A1/Niagaran	LS/Dolo.	3
Denbury Resources	Lazy Creek	Miss.	Pike	12/01	840	5	6	Lower Tuscaloosa	S	23.4
Denbury Resources	Little Creek	Miss.	Lincoln & Pike	1985	6,200	30	34	Lower Tuscaloosa	S	23
Denbury Resources	Lockhart Crossing	La.	Livingston	12/07	3,398	11	3	First Wilcox	S	21
Denbury Resources	West Mallalieu	Miss.	Lincoln	1986	8,240	42	31	Lower Tuscaloosa	S	26
Denbury Resources	Martinville	Miss.	Simpson	3/06	280	5	1	Mooringsport	S	18
Denbury Resources	Martinville	Miss.	Simpson	3/06	212	2	2	Rodessa	S	12
Denbury Resources	McComb	Miss.	Pike	11/03	12,600	37	21	Lower Tuscaloosa	S	26
Denbury Resources	Smithdale	Miss.	Amite	3/05	4,100	5	3	Lower Tuscaloosa	S	23
Denbury Resources	Soso	Miss.	Jones/Jasper/ Smith	4/06	2,600	37	17	Bailey 11701	S	17.4
Denbury Resources	Soso	Miss.	Jones/Jasper/ Smith	4/06	1,800	16	8	Rodessa 11180	S	16.8
Denbury Resources	Brookhaven	Miss.	Lincoln	1/05	10,800	31	23	Lower Tuscaloosa	S	25.5
Denbury Resources	East Mallalieu	Miss.	Lincoln	12/03	880	11	8	Lower Tuscaloosa	S	26
Denbury Resources	Tinsley	Miss.	Yazoo	9/07	10,104		6	Woodruff	S	21
Energen Resources	East Penwell (SA) Unit	Tex.	Ector	5/96	1,020	47	22	San Andres	Dolo.	10
ExxonMobil	Greater Aneth Area	Utah	San Juan	2/85	13,440	143	120	Ismay Desert Creek	LS	14
ExxonMobil	Means (San Andres)	Tex.	Andrews	11/83	8,500	484	284	San Andres	Dolo.	9
Fasken	Hanford	Tex.	Gaines	7/86	1,120	23	26	San Andres	Dolo.	10.5
Fasken	Hanford East	Tex.	Gaines	3/97	340	7	4	San Andres	Dolo.	10
Great Western Drilling	Twofreds	Tex.	Loving, Ward, Reeves	1/74	4,392	32	9	Delawar, Ramsey	S	19.5
George R. Brown	Garza	Tex.		5/06	650			San Andres		
Hess	Adair San Andres Unit	Tex.	Gaines	11/97	1,100	19	18	San Andres	Dolo.	15
Hess	Seminole Unit-Main Pay Zone	Tex.	Gaines	7/83	15,699	408	160	San Andres	Dolo.	12
Hess	Seminole Unit-ROZ Phase 1	Tex.	Gaines	7/96	500	15	10	San Andres	Dolo.	12
Hess	Seminole Unit-ROZ Phase 2	Tex.	Gaines	4/04	480	16	9	San Andres	Dolo.	12
Hess	Seminole Unit-ROZ Phase 1	Tex.	Gaines	4/04	480	16	9	San Andres	Dolo.	12
Hess	Seminole Unit-ROZ Stage 1	Tex.	Gaines	12/07		6	2	San Andres	Dolo.	12
Kinder Morgan	SACROC	Tex	Scurry	1/72	49,900	391	444	Canyon	LS	4
Merit Energy	Lost Soldier	Wyo.	Sweetwater	5/89	1,345	33	39	Tensleep	S	9.9
Merit Energy	Lost Soldier	Wyo.	Sweetwater	5/89	790	16	17	Darwin-Madison	S/LS-Dolo.	10.3
Merit Energy	Lost Soldier	Wyo.	Sweetwater	6/96	120	11	7	Cambrian	S	7
Merit Energy	Wertz	Wyo.	Carbon, Sweetwater	10/86	1,400	12	22	Tensleep	S	10
Merit Energy	Wertz	Wyo.	Carbon, Sweetwater	9/00	810	12	18	Darwin-Madison	S/LS-Dolo.	10
Merit Energy	Northeast Purdy	Okla.	Garvin	9/82	3,400	85	49	Springer	S	13
Merit Energy	Bradley Unit	Okla.	Garvin/Grady	2/97	700	29	12	Springer	S	14
Murfin Drilling	Hall-Gurney	Kan.	Russell	12/03	10	2	3	LKC C	LS	25
Orla Petco	East Ford	Tex.	Reeves	7/95	1,953	8	4	Delaware, Ramsey	S	23
Occidental	Alex Slaughter Estate	Tex.	Hockley	8/00	246	21	14	San Andres	Dolo./LS	10
Occidental	Anton Irish	Tex.	Hale	4/97	4,437	112	94	Clearfork	Dolo.	7
Occidental	Cedar Lake	Tex.	Gaines	8/94	2,870	159	98	San Andres	Dolo.	14
Occidental	Central Mallet Unit	Tex.	Hockley	1984	6,412	182	136	San Andres	Dolo./LS	11
Occidental	Cogdell	Tex.	Scurry/Kent	10/01	2,684	93	55	Canyon Reef	LS	13

TABLE C

Permeability, md	Depth, ft	Gravity, °API	Oil, cp	Oil, °F.	Prev. prod.	Satur. % start	Satur. % end	Proj. matur.	Tot. prod., b/d	Enh. prod., b/d	Proj. eval.	Profit	Project scope
30	5,000	43	0.6	120	Prim., WF	39	24	HF	3,000	3,000	Succ.	Yes	RW, Exp. L
75	1,900	37	0.6		Prim., GI, WF	39	24	JS	5,000	6,000	Succ.	Yes	RW, Exp. L
30	1,500	35	0.6	99	Prim., WF	39	24	JS			Prom.		P, Exp. L
16	9,000	30	2.0	200	WF			NC			Prom.		P
6	4,900	32	1	110	WF			HF	600	580	Succ.	Yes	LW
3	5,000	32	2	107	WF	45	8	JS	5,800	4,000	Succ.	Yes	LW
70	6,200	30	3	115	WF	59	42	HF	1,100	1,100	Succ.	Yes	FW
63	7,260	38.5	2	152	WF	52		JS	1,275	1,175	Succ.	Yes	Phase 1&2 (1/2FW)
63	7,300	38	2	152	WF	52		JS	200	170	TETT	TETT	Phase 1
10	6,000	35	2	160	WF	38	29	JS	15,300	11,600	Succ.	Yes	FW
4	4,700	32	2	104	WF	36	10	NC	3,100	2,000	Succ.	Yes	Exp. L
6	4,950	33	1	105	WF	41	25	HF	5,950	4,747	Succ.	Yes	LW
22	4,550	38	1	101	WF	36	15	HF	4,500	2,950	Succ.	Yes	LW
11	4,500	38	1	101	Prim.	70	50	JS	450	250	Succ.	Yes	FW
11	4,500	38	1	101	Prim.	70	50	HF	6,200	5,200	Succ.	Yes	FW
0.1-100	5,450	43	0.8	103	Prim.	54	44	JS	10	10	TETT		Exp. L
0.1-100	5,450	42	0.8	103	Prim.	47	40	JS	75	75	Succ.		Exp. L
10	5,400	43	0.8	108	Prim.			NC		75	Succ.		RW
0.1-100	5,500	43	0.8	100	Prim	51	40	C	0	0	Succ.		FW
5	5,400	43	0.8	108	Prim.			HF		76	Succ.		RW
0.1-100	5,500	41	0.8	101	Prim.	51	35	JS	210	210	Succ.		FW
5	5,500	41	0.8	108	Prim.			JS		125	TETT		RW
0.1-100	5,600	42	0.8	102	Prim.	52	42	HF	70	70	Succ.		FW
65	10,400	39		242	Prim.	27.4		JS	250	250	TETT		FW
90	10,750	40		250	WF	44	21	NC	1,650	1,650	Succ.		FW
50-4,000	10,100	38.9	0.35	212	WF	60.4		JS			TETT		FW
75	10,550	40		248	Prim.	44	21	HF	6,200	6,200	Succ.		FW
40	11,000	38		244	WF	54.7		JS	600	650	Succ.		RW
200	11,600	42		250	WF	63.5		JS	180	180	TETT		Exp. L
90	10,900	40		250	Prim./WF	52		JS	1,650	1,650	Prom.		Exp. L
90	11,000	41		250	Prim.	50		JS	600	600	TETT		Exp. L
273	11,950	43		234	Prim.	50.4		JS	1,350	1,350	Prom.		Exp. L
171	11,500	45		228	WF	54.7		JS	350	350	Prom.		Exp. L
60	10,300	40		250	Prim./GI/WF	47		JS	3,100	3,100	Prom.		Exp. L
75	10,550	40		248	Prim./WF	44		JS	1,800	1,800	Prom.		Exp. L
289	4,800	33		164	Prim./ WF	24		JS	440		TETT		FW
4	4,000	34	2	86	WF	55	40	JS	766	450	Prom.	Yes	RW
5	5,600	41	1	125	Prim.	50		JS	6,000	3,000	Succ.	Yes	LW
20	4,300	29	6	97	WF			HF	10,000	8,700	Succ.	Yes	FW
4	5,500	32	1	104	Prim.	60.7	18.7	NC	300	300	Succ.		LW
4	5,500	32	1	104	WF	45	18.7	HF	45	45	Succ.		LW
32	4,900	36	2	105	WF	50		NC	170	170	Succ.	Yes	FW
	3,000	36											
8	4,852	35	1	98	WF			JS	2,300	900	Prom.		P
1.3-123	5,300	35	1	104	WF			HF	19,500	19,500	Succ.	Yes	FW
1.3-123	5,500	35	1	104	none			HF	1,200	1,200	Prom.		P
1.3-123	5,500	35	1	104	none			HF	1,800	1,800	Prom.		P
1.3-123	5,500	35	1	104	none			JS	1,800	1,800	Prom.		P
1.3-123	5,500	35	1	104	none			JS	50	50	Prom.		P
19	6,700	39	1	135	Prim./WF	63	39	HF	24,980	24,227	Succ.	Yes	FW
31	5,000	35	1	178	WF			NC	4,672	4,545	Succ.	Yes	FW
4	5,400	35	1	181	WF			NC	2,232	1,661	Succ.	Yes	FW
10	7,000	35			WF			JS	1,740	1,015	Succ.	Yes	FW
20	6,000	35	1	163	WF			NC	3,912	2,986	Succ.	Yes	FW
5	6,400	35	1	170	WF			NC	1,685	1,033	Succ.	Yes	FW
44	9,400	38	1	148	WF			HF	1,800	1,800	Succ.		FW
50	9,400	38	1	150	WF			JS	800	600	Prom.		FW, Exp. L
85	2,900	39.6	3	99	WF	35		NC	3.3	3.3	Disc.	No	P
30	2,680	40	1	82	Prim.	49	36	HF	128	128	Disc.	No	FW
5	4,950	31	1.8	105	WF	40	25	HF	370	300	Succ.	Yes	FW
4	5,800	30	3.0	109	Prim., WF	50	30	HF	5,100	4,000	Succ.	Yes	Exp. L
5	4,800	32	2.3	102	WF	50	15	HF	4,950	2,860	Succ.	Yes	LW
2	4,900	31	1.8	105	WF	48	25	HF	2,900	2,100	Succ.	Yes	FW
6	6,800	40	0.7	130	WF	46	15	HF	6,460	5,900	Succ.	Yes	Exp. L

PRODUCING CO_2, OTHER GAS, AND CHEMICAL EOR IN US (CONTINUED)

Type and operator	Field	State	County	Start date	Area, acres	No. wells prod.	No. wells inj.	Pay zone	Formation	Porosity, %
Occidental	El Mar	Tex.	Loving	4/94	6,000	64	32	Delaware	S	22
Occidental	Frazier Unit	Tex.	Hockley	12/84	1,600	67	52	San Andres	Dolo./LS	10
Occidental	GMK South	Tex.	Gaines	1982	1,143	16	7	San Andres	Dolo.	10
Occidental	Igoe Smith	Tex.	Cochran	9/05	1,235	61	27	San Andres	Dolo.	11
Occidental	Levelland	Tex.	Hockley	9/04	1,179	84	51	San Andres	Dolo.	12
Occidental	Mid Cross-Devonian Unit	Tex.	Crane, Upton & Crockett	7/97	1,326	13	5	Devonian	Tripol.	18
Occidental	N. Cross-Devonian Unit	Tex.	Crane & Upton	4/72	1,155	26	13	Devonian	Tripol.	22
Occidental	North Cowden Demo.	Tex.	Ector	2/95	200	10	3	Grayburg	Dolo.	10
Occidental	North Dollarhide	Tex.	Andrews	11/97	1,280	28	20	Devonian	Tripol.	22
Occidental	North Hobbs	NM	Lea	3/03	3,100	125	75	San Andres	Dolo.	15
Occidental	S. Cross-Devonian Unit	Tex.	Crockett	6/88	2,090	73	30	Devonian	Tripol.	21
Occidental	Salt Creek	Tex.	Kent	10/93	12,000	174	135	Canyon	LS	20
Occidental	Sharon Ridge	Tex.	Scurry	2/99	1,400	31	18	Canyon Reef	LS	10
Occidental	Slaughter (H T Boyd Lease)	Tex.	Cochran	8/01	1,240	37	24	San Andres	Dolo.	10
Occidental	Slaughter Estate Unit	Tex.	Hockley	12/84	5,700	194	150	San Andres	Dolo./LS	12
Occidental	Slaughter North West Mallet	Tex.	Cochran & Hockley	2008	1,048	39	24	San Andres	Dolo.	10
Occidental	Slaughter West RKM Unit	Tex.	Hockley	2006	1,204	51	33	San Andres	Dolo.	9
Occidental	South Welch	Tex.	Dawson	9/93	1,160	89	70	San Andres	Dolo.	11
Occidental	T-Star (Slaughter Consolidated)	Tex.	Hockley	7/99	1,700	51	35	Abo	Dolo.	7
Occidental	Wasson Bennett Ranch Unit	Tex.	Yoakum	6/95	1,780	115	89	San Andres	Dolo.	11
Occidental	Wasson Denver Unit	Tex.	Yoakum & Gaines	4/83	27,848	1,010	575	San Andres	Dolo.	12
Occidental	Wasson ODC Unit	Tex.	Yoakum	11/84	7,800	325	270	San Andres	Dolo./LS	10
Occidental	Wasson Willard Unit	Tex.	Yoakum	1/86	8,500	275	228	San Andres	Dolo.	10
Occidental	West Welch	Tex.	Gaines	10/97	240	0	0	San Andres	Dolo.	10
Pure Resources	Dollarhide (Devonian) Unit	Tex.	Andrews	5/85	6,183	83	66	Devonian	Dolo./Tripolitic chert	13.5
Pure Resources	Dollarhide (Clearfork "AB") Unit	Tex.	Andrews	11/95	160	21	4	Clearfork	Dolo.	11.5
Pure Resources	Reinecke	Tex.	Borden	1/98	700	32	8	Cisco Canyon Reef	LS/Dolo.	10.4
Resolute Natural Resources	Greater Aneth	Utah	San Juan	10/98	1,200	12	10	Desert Creek	LS	12
Stanberry Oil	Hansford Marmaton	Tex.	Hansford	6/80	2,010	5	6	Marmaton	S	18.1
Whiting Petroleum	North Ward Estes	Tex.	Ward/Winkler	5/07	16,300	816	816	Yates	SS	16
Whiting Petroleum	Postle	Okla.	Texas	11/95	11,000	92	82	Morrow	SS	16
Whiting Petroleum	Postle Expansion	Okla.	Texas	1/07-1/09	7,000	72	62	Morrow	SS	16
XTO Energy Inc.	Goldsmith	Tex.	Ector	12/96	330	16	9	San Andres	Dolo.	11.6
XTO Energy Inc.	Cordona Lake	Tex.	Crane	12/85	2,084	64	26	Devonian	Tripol.	22
XTO Energy Inc.	Wasson (Cornell Unit)	Tex.	Yoakum	7/85	1,923	90	62	San Andres	Dolo.	8.6
XTO Energy Inc.	Wasson (Mahoney)	Tex.	Yoakum	10/85	640	45	30	San Andres	Dolo.	13
CO_2 immiscible										
Anadarko	Salt Creek	Wyo.	Natrona	10/05	5	4	1	Wall Creek 1 (Frontier)	S	17
Chaparral Energy	Sho-Vel-Tum	Okla.	Stephens	11/98	98	6	1	Aldridge	S	20
Denbury	Eucutta	Miss.	Wayne	4/06	2,100	25	29	Eutaw	S	27
Denbury	Martinville	Miss.	Simpson	3/06	180	3	1	Wash-Fred 8500	S	26
Kinder Morgan	Yates	Tex.	Pecos	3/04	26,000	551	121	San Andres	Dolo.	17
Hydrocarbon miscible										
BP Alaska	Prudhoe Bay	Alas.		12/82-2/87	55,000	376	162	Sadlerochit	S	22
BP Alaska	Eileen West End	Alas.		12/02	4,000	40	16	Sadlerochit	S	19
BP Alaska	Aurora	Alas.		12/03	10,000	16	12	Kuparuk River	S	20
BP Alaska	Borealis	Alas.		2004	9,000	31	19	Kuparuk River	S	20
BP Alaska	Orion	Alas.		2006	11,000	9	23	Schrader Bluff	S	25
BP Alaska	Polaris	Alas.		2004	5,000	8	10	Schrader Bluff	S	25
BP Alaska	Pt. McIntyre	Alas.		2001	6,240	55	15	Kuparuk River	S	23
ExxonMobil	South Pass Block 89	OCS		12/83	204	9	5	X and Y Series	S	26
ExxonMobil	South Pass Block 89	OCS		7/89	20	3	3	X Series	S	26
ConocoPhillips	Kuparuk River	Alas.		6/88-12/96	70,000	350	260	Kuparuk A&C	S	24
ConocoPhillips	Tarn	Alas.		11/98	2,400	29	11	Bermuda	S	21
ConocoPhillips	Alpine	Alas.		11/00	40,000	25	22	Alpine	S	19
Hydrocarbon immiscible										
BP Alaska	Milne Point	Alas.		3/95	20,000	100	90	Kuparuk River	S	22
Nitrogen miscible										
ExxonMobil	Jay-Little Escambia Creek	Fla./Ala.	Santa Rosa/ Escambia	1/81	14,415	53	38	Smackover	LS	14
Nitrogen immiscible										
ExxonMobil	Hawkins	Tex.	Wood	8/87	2,800	27	6	Woodbine-East FB	S	28
ExxonMobil	Hawkins	Tex.	Wood	1/94	7,790	267	20	Woodbine-West FB	S	28
Occidental	Elk Hills	Calif.	Kern	2005		800	60	Sub Scalez	S	28
Chemical, polymer, surfactant										
Cano	Delaware-Childers	Okla.	Nowata	6/06	20			Bartlesville		
Chaparral Energy	North Burbank	Okla.	Osage	12/07	480	19	9	Burbank	S	16.8

Table C

Perme-ability, md	Depth, ft	Gravity, °API	Oil, cp	Oil, °F.	Prev. prod.	Satur. % start	Satur. % end	Proj. matur.	Tot. prod., b/d	Enh. prod., b/d	Proj. eval.	Profit	Project scope
24	4,500	41	1.1	97	Prim./WF	40		NC	350	270	Disc.	Yes	Exp. UL
4	4,950	31	1.8	105	WF	38	23	HF	1,250	925	Succ.	Yes	FW
3	5,400	30	3.0	101	WF	55	28	HF	610	375	Succ.	Yes	LW
4	5,040	34	1.5	105	WF	47	36	HF	700	440	Succ.		Exp. L
2	4,900	34	1.4	108	WF	45	30	JS	1,800	950	Succ.	Yes	Exp. L
2	5,400	42	0.4	104	Prim., GI	60	20	HF	320	296	Disc.	Yes	FW
5	5,300	44	0.4	104	Prim., GI	49	21	NC	1,045	835	Succ.	Yes	FW
2-5	4,200	34	1.5	91	WF	40	25	NC	230	80	Succ.	Yes	P
5	7,500	40	0.5	123	WF	38	23	HF	1,950	1,000	Succ.	Yes	FW
15	4,200	35	0.9	102	WF	35	24	HF	8,560	6,300	Succ.	Yes	Exp. L
4	5,200	43	0.6	104	Prim., GI	43	24	HF	5,875	5,790	Succ.	Yes	FW
12	6,300	39	1.0	125	WF	89	15	HF	7,700	6,600	Succ.	Yes	LW
70	6,600	43	0.4	125	WF	39	26	HF	900	400	Succ.	Yes	Exp. L
4	5,000	31	1.6	108	WF	47	36	NC	1,080	1,040	Succ.	Yes	LW
5	4,950	31	1.8	105	WF	40	23	HF	4,100	2,430	Succ.	Yes	FW
4	4,950	32	2.0	105	WF	47	31	PP	950	0	TETT		
4	4,900	32	2.0	105	WF	42	29	JS	1,560	30	TETT		
4	4,900	34	2.3	98	WF	50	15	HF	1,180	865	Succ.	Yes	Exp. L
2	7,850	28	1.9	134	Prim./WF	75	45	HF	2,100	2,100	Succ.	Yes	Exp. L
8	5,250	34	1.2	105	WF	55	37	HF	4,320	3,510	Succ.	Yes	Exp. L
8	5,200	33	1.2	105	WF	51	31	HF	31,500	26,850	Succ.	Yes	FW
5	5,100	34	1.3	110	WF	49	34	HF	9,900	9,200	Succ.	Yes	FW
1.5	5,100	32	2.0	105	WF	56	41	HF	4,965	4,765	Succ.	Yes	Exp. L
3	4,900	34	2.3	98	WF	50	15	C	1,790	0	Disc.	No	P
9	8,000	40	0	122	Prim./WF	35	22	HF	2,420	1,970	Succ.	Yes	FW
4	6,500	40	1	113	Prim./WF	30	10	JS	230	124	Prom.	Yes	Exp. L
170	6,700	43.5	0.4	139	WF	35	10	JS	977	830	Succ.	Yes	Exp. L
18.3	5,700	42	1.5	129	WF	40	28	JS	1,200	400	Prom.	Yes	P
48	6,500	44	2	142	Prim.	43		NC	102	102	Succ.	Yes	FW
37	2,600	36	1.6	83	Prim., WF	26.5	21	JS	4,225	700	Prom.	Yes	FW
50	6,200	40	1	145	WF	37	25	HF	4,500	4,500	Succ.		Exp. L
35	6,200	40	1	145	WF	37	25		1,700	1,700	Early succ.		Exp. L
32	4,200	34	0.98	104	WF			JS	120	20	TETT		P
4	5,500	40	0.50	101	WF			HF	1,350	400	Prom.	Yes	LW
2	4,500	33	1.00	106	WF			HF	1,675	800	Succ.	Yes	LW
6	5,100	33	0.97	110	WF	54.4	39.2	HF	1,875	1,450	Succ.	Yes	LW
30	1,150	35	0.6	99	Prim., WF	32	24	C			Prom.		P, Exp. L
270	5,400	19	45	105	Prim.	62	47	JS	72	70	Prom.	Yes	RW
250	5,050	22		152	WF	42		JS	3,000	3,000	Prom.		FW
1,000	8,500	11		198	Prim.	44.3		JS	270	0	TETT		RW
175	1,400	30	6	82	GI	75	54	JS	27,940	6,280	Succ.	Yes	FW
400	8,800	27	0.9	210	WF	50		HF	100,000	28,000	Succ.		FW
130	8,800	26	1	235	WF	45		JS	12,000	1,200	Succ.		FW
50	6,700	24	2	150	WF	80		JS	9,500	2,600	Succ.		FW
100	6,600	24-28	2	160	WF	80		JS	12,700	3,700	Succ.		FW
150	4,500	15-23	7-140	85	WF	65		JS	12,500	0	TETT		FW
150	4,900	15-23	7-140	100	WF	65		NS	4,000		TETT		FW
200	8,800	27	0.9	182	WF	70		HF	30,000	7,000	Succ.		FW
1,000-1,500	10,000	38	0.40-0.60	180	Prim.			HF	2,100	2,100	Succ.	Yes	RW
1,000	11,000	38	1	165	Prim.			NC	200	200	Succ.	Yes	RW
50-500	6,000	24	2.0	160	WF/HC Imm.	75		JS	140,000	33,000	Succ.	Yes	Exp. L
20	5,200	37	0.6	142	None	65		JS	22,000		Succ.	Yes	RW
20	7,000	40	0.45	160	None	80		JS	95,000		Prom.	Yes	Exp. L
40	7,000	22	4	170	WF	75			33,600	3,200	Succ.		FW
35	15,400	51	0.2	285	WF			NC	10,700	10,700	Succ.	Yes	FW
2,800	4,600	16	25	168				NC	1,500	1,000	Succ.	Yes	RW
2,800	4,600	24	4	168				JS	9,000	3,000	Prom.		RW
1,500	2,500	25	20.0	110		60	10		20,000	5,000			
	625	32											
50	2,900	39	3	122	WF	53	47	JS	110	0	TETT	TETT	Phase 1

PRODUCING CANADIAN EOR PROJECTS

Type and operator	Field	Province	Start date	Area, acres	No. wells prod.	No. wells inj.	Pay zone	Formation	Porosity, %	Permeability, md
Acid gas miscible										
Apache Canada	Zama-Keg River	Alta.	6/04	3,840	12	12	Zama-Keg River	Dolo.	8	10-100
CO_2 miscible										
Anadarko Canada	Enchant	Alta.	9/04		3	1	Nisku	Dolo.	10-17	10-50
Apache Canada	Midale	Sask.	10/05	30,483	43	5	Marly & Vuggy	Dolo., LS	16.3	7.5
Devon Canada	Swan Hills	Alta.	10/04		5	1	Beaverhill Lake	LS	8.5	54
EnCana	Weyburn Unit	Sask.	9/00	13,800	403	122	Midale	Dolo., LS	15	10
Pengrowth Corp.	Judy Creek	Alta.	2/07	80	4	1	Swan Hills	LS	12	50
Penn West Energy Trust	Jofre	Alta	1/84	6,625	33	15	Viking	S	13	500
Penn West Energy Trust	Pembina	Alta.	3/05	80	6	2	Cardium	S	16	20
Combustion										
Crescent Point Energy Trust	Battrum	Sask.	10/66	4,920	82	25	Battrum/Roseray	S	26	1,265
Crescent Point Energy Trust	Battrum	Sask.	8/67	2,400	26	4	Battrum/Roseray	S	25	930
Crescent Point Energy Trust	Battrum	Sask.	11/65	680	37	9	Roseray	S	27	930
Hydrocarbon miscible										
Burlington Resources	Brassey	B.C.	8/89	6,043	6	6	Artex Triassic	S	16.6	137
Burlington Resources	Fenn-Big Valley	Alta.	4/83	1,268	26	7	Nisku	Dolo.	8	400
Conoco Canada	Goose River	Alta.	4/87	2,847	36	14	Beaverhill Lake/ Swan Hills	LS	8-18	3-270
Devon Canada	Swan Hills	Alta.	10/85	19,440	400	95	Beaverhill Lake	LS	8.5	54
ExxonMobil Oil Canada	Rainbow 'II'	Alta.	7/83	320	2	0	Keg River	Dolo., LS	8.5	100-5,000
ExxonMobil Oil Canada	Rainbow 'AA'	Alta.	9/72	800	4	0	Keg River	Dolo., LS	8.6	100-5,000
ExxonMobil Oil Canada	Rainbow South 'B'	Alta.	8/72	490	8	3	Keg River	Dolo.	6	40
Husky Oil	Rainbow KR B Pool	Alta.	6/84	2,500	69	11	Keg River	Dolo.	8	300
Husky Oil	Rainbow South KR E Pool	Alta.	4/94	478	6	3	Keg River	LS	9.1	50
Husky Oil	Rainbow South KR G Pool	Alta.	5/95	240	3	2	Keg River	LS	8	50
Husky Oil	Rainbow KR F Pool	Alta	6/96	1,920	38	11	Keg River	Dolo.	6	1,000
Imperial Oil	Pembina 'G' Pool	Alta.	9/89	328	2	0	Nisku	Dolo.	8	900
Imperial Oil	Pembina 'K' Pool	Alta.	1984	126	1	0	Nisku	Dolo.	12.7	2,020
Imperial Oil	Pembina 'L' Pool	Alta.	1985	625	4	1	Nisku	Dolo.	10.5	1,060
Imperial Oil	Pembina 'M' Pool	Alta.	1983	192	2	1	Nisku	Dolo.	9	540
Imperial Oil	Pembina 'O' Pool	Alta.	11/83	346	3	0	Nisku	Dolo.	11.8	3,100
Imperial Oil	Pembina 'P' Pool	Alta.	10/83	420	3	1	Nisku	Dolo.	10.3	2,400
Imperial Oil	Pembina 'Q' Pool	Alta.	2/85	301	1	0	Nisku	Dolo.	9.8	1,970
Imperial Oil	Wizard Lake	Alta.	1969	2,725	20	0	Leduc D-3A	Dolo.	10.5	1,375
Imperial Oil	Rainbow "FF" Pool	Alta.	9/71	102	1	0	Keg River	Dolo.	7.3	180
Imperial Oil	Rainbow "T" Pool	Alta.	6/69	222	2	0	Keg River	Dolo.	8.6	320
Imperial Oil	Rainbow "Z" Pool	Alta.	2/71	221	2	1	Keg River	Dolo.	4.25	160
Steam										
CNRL	Tangleflags	Sask.	1987	285	10	10	Lloydminster	S	32.5	3,000-5,000
CNRL	Primrose	Alta.	1985	160,000	750		Clearwater	S	32	2,000-4,000
Devon Canada	Athabasca Oil Sands	Alta.	7/84	50,000	3	3	McMurray	US	30-35	0.1-10
Encana	Foster Creek	Alta.	5/97		27	27	McMurray	S	33	7,000
Encana	Christian Lake	Alta.	2003		6	6	McMurray	S		
Husky Oil	Pikes Peak	Sask.	1/81	400	102	27	Waseca	US	33	7,500
Imperial Oil	Cold Lake	Alta.	1964		4,000	4,000	Clearwater	US	35	1,500
Imperial Oil	Cold Lake (Enhanced cyclic steam)	Alta.	2002	32	20	8	Clearwater	US	32	2,000
Japan Canada Oil Sands	Hangingstone	Alta.	1997	2,400	15	15	McMurray	S		
Petro-Canada	MacKay	Alta.	2002		50	50				
Shell Canada	Orion	Alta.	9/07	5,120	22	22	Clearwater	S	33	2,000
Shell Canada	Peace River	Alta.	1979	4,900	97	109	Bluesky	S	26.5	2,000-4,000
Shell Canada	Peace River	Alta.	10/86	3,000	48	48	Cretaceous-Bullhead	S	28.5	100-2,000
Suncor	Firebag	Alta.	2003							
Nitrogen										
Talisman	Turner Valley	Sask.	2001							
Polymer										
CNRL	Pelican Lake	Alta.	2006	187,000	1,000	200	Wabiskaw	S	29	1,000-4,000

Table D

Depth, ft	Gravity, °API	Oil, cp	Oil, °F.	Prev. prod.	Satur. % start	Satur. % end	Proj. matur.	Tot. prod., b/d	Enh. prod., b/d	Proj. eval.	Profit	Project scope
4,900	32-40	0.6-1.5	160-176	Prim.	40	5	JS	1,000	1,000	Prom.	Yes	Exp. L
4,600	29	2.2	95	WF			JS	170		TETT		P
4,600	30	3	149	WF	45		JS	5,900		Prom.	Yes	FW
8,300	41	0.4	225		30	5	JS					P
4,655	28	3	140	WF	45	30	JS	20,900	16,500	Prom.		LW, Exp. L
8,200	41.5	0.65	206	HC			JS			TETT		P
4,900	42	1.14	133	WF	38	23	HF	700	700	Succ.		FW
5,300	41	1	128	WF			JS			TETT		P
2,900	18	70.3	110	Prim.	66		HF	3,200	3,200	Succ.	Yes	FW
2,900	18	70	110	Prim.	62		HF	800	800	Succ.	Yes	FW
2,900	18	70	110	Prim.	70		HF	800	800	Succ.	Yes	FW
9,850	57	0.097	210		98	33	NC	1,500	1,500	Succ.	Yes	FW
5,249	32.8	1.34	136	Prim.	33		HF	590	590	Succ.	Yes	FW
9,150	41	0.3	230	WF	55	43	NC	1,900	1,700	Succ.		Exp. UL
8,300	41	0.4	225	WF	30	5	NC	14,300	4,100	Succ.	Yes	FW (Exp. L)
5,500	39	0.46	190	WF	45	15	HF	50	50	Prom.	Yes	FW
5,500	39	0.47	184	GI/WF	92	15	NC	10	10	Succ.	Yes	FW
6,200	40	0.3	183	Prim.			NC	598	598	Succ.	Yes	FW
6,000	38	0.83	188	WF	52	23	HF	8,810	8,810	Succ.	Yes	RW
6,400	43	0.39	195	WF	67	50	Term.	189	189	Disc.	Yes	RW
6,330	44	0.4	195	WF	67	50	Term.	19	19	Disc.	Yes	RW
6,000	48	0.25	180	WF/GI	50	35	JS	3,200	3,200	Succ.	Yes	RW
9,541	43.2	0.33	204	Prim.	80	5	NC	409	409	Succ.	Yes	FW
9,469	43.6	0.37	198	Prim.	82	5	NC	208	208	Succ.	Yes	FW
9,415	40.9	0.42	199	WF	88	5	NC	667	667	Succ.	Yes	FW
9,333	41.1	0.14	198	Prim.	93	5	NC	472	472	Succ.	Yes	FW
9,332	43.4	0.32	190	Prim.	84	5	NC	198	198	Succ.	Yes	FW
9,531	45.4	0.36	200	Prim.	87	5	NC	340	340	Succ.	Yes	FW
9,421	41.3	0.42	196	Prim.	91	5	NC	220	220	Succ.	Yes	FW
6,500	38	0.54	167	Prim.	93	12	NC	346	346	Succ.	Yes	FW
4,160	37	0.59	188	Prim.	90	5	NC	17	17	Succ.	Yes	RW
4,330	40	0.69	188	Prim.	88	5	NC	161	161	Succ.	Yes	RW
4,040	38	0.547	190	Prim.	73.5	5	NC	418	418	Succ.	Yes	RW
1,480	13	13,000	66	Prim.	90	38	TBD	5,000	5,000	Succ.	Yes	TBD
1,600	10-12	40,000-300,000	60	0	60	30	TBD	70,000	70,000	Succ.	Yes	TBD
500	8	5,000,000	45		85	15	HF	2,500-3,000	2,500-3,000	Succ.	Yes	Exp. L
1,600	10	500,000	55		85		JS	35,000	35,000			
							JS	7,000	7,000			
1,640	12	25,000	70		85		HF	7,500	7,500	Succ.	Yes	RW
1,509	10.2	100,000	55		70		HF	154,000	154,000	Succ.		FW
1,395	10	200,000	55	CS	70		HF			Prom.		P
1,000							JS	9,000	9,000			P
							JS	30,000	30,000			
1,350	10	75,000	60	SAGD	70	10	JS	10,000		TETT		Exp. L
1,800	8	40,000-400,000	63	SF, SD, SS	0.8	0.54	HF	13,000	13,000	Succ.	Marginal	P, Exp. L
1,800	8	100,000	62		80		JS	5,000	5,000	Succ.		Exp. L
												P
1,500	13	1,000-4,000	60	Prim.	70	40	TBD	40,000	20,000	Succ.	Yes	TBD

PRODUCING EOR PROJECTS OUTSIDE US AND CANADA

Type and operator	Operator	Type project	Field	Start date	Area, acres	No. wells prod.	No. wells inj.	Pay zone	Formation	Porosity, %
Argentina										
Chubut	Tecpetrol	Polymer	El Tordillo	11/05	552	74	15	57	S	24
Brazil										
Bahia	Petrobras	CO_2 immiscible	Buracica	1991	1,670		7	Sergi	S	22
Bahia	Petrobras	CO_2 miscible	Rio Pojuca	1999			1	Agua Grande	S	30
Espirito Santo	Petrobras	Steam	Fazenda Alegre	2001	1,255	59		Urucutuca	S	27
Rio Grande do Norte (RN)	Petrobras	Steam	Estreito	1984		700		Acu	S	25
Rio Grande do Norte (RN)	Petrobras	Steam	Alto do Rodrigues	1984		500		Acu	S	25
Sergipe	Petrobras	Steam	Carmopolis	1978		200		Barra Itiuba/ Carmopolis	S/Congl.	22
China										
Heilongjiang Province	Daquin Oilfield Ltd.	Polymer	Daqing	12/03	1,729	121	87	Saertu S1-2	S	27
Heilongjiang Province	Daqing Administration Bureau	Polymer	Daqing	6/99	124	8	6	Saertu S1-2	S	26
Xinjiang Province	Xinjiang Petroleum Adm. Bureau	Polymer	Karamay	5/96		9	4	Karamay	Cong.	21
Jilin Province	CNPC-Jilin	Microbial	Fuju	1994		44	44		S	22-26
Dongyin, Shandong Province	CNPC-Shengli Bureau	Steam	Sanjasi	1984	3,162	280		Ng, Ea, El, Ea	S	30
Dongyin, Shandong Province	CNPC-Shengli Bureau	Steam	Lean	1989	10,613	658		Ea, Ng	S/Congl.	15-30
Liaoling Province	CNPC-Liaohe Bureau	Steam	Gaoshen 2-3	1982	3,583	450		3rd sand	S/Dolo.	20-25
Nanyang, Henan Province	CNPC-Henan Bureau	Steam	Jinglou	1986	1,210	177		E	S	32
Nanyang, Henan Province	CNPC-Henan Bureau	Steam	Gueheng	1987	1,655	132		E	S	27-34
Pnajin, Liaoning Province	CNPC-Liaohe Bureau	Steam	Shu I 7-5	1990	237	38	11	Middle	S	25.6
Pnajin, Liaoning Province	CNPC-Liaohe Bureau	Steam	Shu I	1984	5,718	1,149		Middle & Upper	S	23-28
Pnajin, Liaoning Province	CNPC-Liaohe Bureau	Steam	Xiao Wa	1992	2,100	311		2nd Dongying, 3rd sand	S	27.5
Pnajin, Liaoning Province	CNPC-Liaohe Bureau	Steam	Huanxiling	1985	7,067	1,848		2nd and 3rd sand	S	32
Xinjiang Province	CNPC-Xinjiang Bureau	Steam	Karamay 9-1	1984	469	128	41	Qigu	S	32
Xinjiang Province	CNPC-Xinjiang Bureau	Steam	Karamay 9-2	1986	444	79	21	Qigu	S	32
Xinjiang Province	CNPC-Xinjiang Bureau	Steam	Karamay 9-3	1986	115	62	31	Qigu	S	31
Xinjiang Province	CNPC-Xinjiang Bureau	Steam	Karamay 9-4	1988	963	358	32	Qigu	S	30
Xinjiang Province	CNPC-Xinjiang Bureau	Steam	Karamay 9-5 - 9-9	1991	2,495	1,136		Qigu	S	32
Xinjiang Province	CNPC-Xinjiang Bureau	Steam	Karamay 6	1989	963	211	45	Qigu	S	31
Heilongjiang Province	CNPC-Daqing	Polymer	Lamadian-2	1/94	516	21	9	K	S	26
Heilongjiang Province	CNPC-Daqing	Polymer	Sarto	1/93	273	36	25	K	S	25
Heilongjiang Province	CNPC-Daqing	Polymer	Lamadian-1	6/94	559	25	16	K	S	26
Henan Province	CNPC-Henan	Polymer	Shuanghe	2/96	744	12	3	E	S	20
Jilin Province	CNPC-Jilin	Polymer	Fuyu	6/93	519	86	21	K	S	25
Liaoling Province	CNPC-Liaohe Bureau	Polymer	Huanxiling-16	3/93	346	11	3	B	S	28.5
Shandong Province	CNPC-Shengli Bureau	Polymer	Guodao, Pilpt	9/92	138	10	4	N	S	32
Shandong Province	CNPC-Shengli Bureau	Polymer	Guodong	1/91	1,008	52	39	N	S	33
Shandong Province	CNPC-Shengli Bureau	Polymer	Guodao	12/94		82	40	N	S	32
Tianjin City	CNPC-Dagang	Polymer	Gangxi 3-2, West	12/91	255	19	6	N	S	31
Tianjin City	CNPC-Dagang	Polymer	Dagang-West	10/91	277	11	6	N	S	31
Daqing	CNPC, Liupukang	Polymer		7/96	3,803			K		
Daqing	CNPC, Liupukang	Polymer		1/97	4,740			K		
Shengli	CNPC, Liupukang	Polymer		8/96	2,989			N		
Shengli	CNPC, Liupukang	Polymer		9/96	1,536			N		
Henan	CNPC, Liupukang	Polymer		9/96	2,717			E		
Nemangu	CNPC, Nemangu	Combustion	Kerxing	1996	6					
Jilin Province	CNPC, Jilin	Microbial		4/96						
Liaoling Province	Qi-40	Steam drive	Panjin	1996	1,962					
Snadong	Cheo-20	Steam drive	Dongyi	1996	964					
Colombia										
Mid. Magdalena Basin	Omimex	Steam	Teca	2/84	3,448	342		Oligocene A & B	S	28
Mid. Magdalena Basin	Omimex	Steam	Teca	1/91	60	20	12	Oligocene B	S	28
Germany										
Lower Saxony, Grafschaft Bentheim	Wintershall Holding AG	Steam	Emlichheim, Block 1	7/07	55	7	1	Valanginian	US	30
Lower Saxony, Grafschaft Bentheim	Wintershall Holding AG	Steam	Emlichheim, Block 2	6/05	22	4	1	Valanginian	US	30
Lower Saxony, Grafschaft Bentheim	Wintershall Holding AG	Steam	Emlichheim, Block 3	8/01	50	7	1	Valanginian	US	30
Lower Saxony, Grafschaft Bentheim	Wintershall Holding AG	Steam	Emlichheim, Block 4 Northeast	2/02	22	5	1	Valanginian	US	30
Lower Saxony, Grafschaft Bentheim	Wintershall Holding AG	Steam	Emlichheim, Block 5/7 North	2/99	58	8	1	Valanginian	US	30
India										
Gujarat	ONGC	Polymer	Jhalora	6/93	11	4	1	Kalol Sand IX+X	S	33
Gujarat	ONGC	Combustion	Balol	3/90	6	4	1	Kalol Sand I	US	28
Gujarat	ONGC	Combustion	Lanwa	8/92	10	4	1	Kalol Sand I	US	30
Gujarat	ONGC	Combustion	Balol	10/96	3,450			Kalol sand-I		
Gujarat	ONGC	Combustion	Santhal	6/96	3,450			Kalol sand-I & II		
Gujarat	ONGC	Combustion	Bechraji	11/96	3,120			Kalol sand-I		
Indonesia										
Pekanbaru	PT Caltex	Steam	Duri	1/85	30,878	2,702	1,068	Pertama - Kedua	US	34
Pekanbaru	PT Caltex	Steam	Duri	7/94	27,000	1,093	532	Rindu	US	38
Mexico										
Bay of Campeche	Pemex	Nitrogen	Cantarell-Akal	5/00		19-22				

TABLE E

Perme-ability, md	Depth, ft	Gravity, °API	Oil, cp	Oil, °F.	Prev. prod.	Satur. % start	Satur. % end	Proj. matur.	Tot. prod., b/d	Enh. prod., b/d	Proj. eval.	Profit	Project scope
500	5,450	21	5	185	WF	50.9	45.2	JS	2,270	604	Succ.	TETT	FW
	1,970	35	10.5	120	Prim, WF			NC			Succ.	Yes	RW
	5,900	36	2	183	Prim			HF			TETT		P
500-2,000	2,300	13	825	124	Prim	76		HF	9,500	9,500	Succ.	Yes	FW
4,000	1,150	15	1,700	100	Prim			NC	5,700	5,700	Succ.	Yes	FW
3,000	1,480	15	2,500	100	Prim			NC	2,500	2,500	Succ.	Yes	FW
200	2,460	21	500	122				NC	3,860	3,860	Succ.	Yes	FW
611	3,116	32	9.3	113	WF			HF		113	Prom.		Exp. L
600	3,268	32	9	113	WF	61.1	46.2	JS	684	809	Prom.	Prom.	P
198	1,063	28	17	74	WF	N/A	N/A	NC	N/A	N/A	Prom.	Prom.	P
180	935-1,572	31.5	19-31	86		54		NC			Succ.	Yes	Exp. L
5,000	3,673-3,938	11-19	9,200	131	Prim.	65		HF	9,116	9,116	Succ.		FW
3,000-4,500	2,885-3,132	11-18	10,000-40,000	129	Prim.	60		HF	21,735	21,735	Succ.		FW
2,200	5,081-5,740	16-19	1,000-2,000	150	Prim.	65		HF	10,136	7,868	Succ.		RW
1,500-3,000	459-1,936	16-25	9,600-16,000	70-90	Prim.	65		HF	1,965	1,965	Succ.		FW
1,351-7,134	513-1,627	14-22	6,000-137,000	66	Prim.	65-73		HF	1,663	1,663	Succ.		FW
1,601	3,345	13	15,000-18,900	129	C	65		HF	2,117	920	Succ.		RW
560-1,500	2,755-5,051	13-20	620-25,900	118-134	Prim.	65		HF	32,124	25,760	Succ.		FW
1,683	3,772-4,592	11-13	4,000-11,000	115-122	Prim.	65		JS	15,020	15,020	Succ.		FW
450-512	2,050-3,440	14	700-14,000	104	Prim.	65		HF	59,595	42,122	Succ.		FW
3,170	820	16-24	2,000	66	Prim.	65		HF	1,329	1,329	Prom.		RW
2,290	754	16-24	2,240	66	Prim.	65		HF	951	951	Prom.		RW
1,730	525-1,180	16-24	4,000	65	Prim.	65		HF	913	913	Disc.		RW
3,000	656-1,312	16-24	7,200	66	Prim.	65		HF	2,709	2,709	Prom.		RW
1,350-2,000	721-1,146	16-24	5,400-54,000	66	Prim.	65		HF	16,632	16,632	Succ.		RW
2,500-3,100	853-1,016	16.5-23	6,400-80,000	66	Prim.	65		HF	2,948	2,948	Succ.		RW
580	3,212	33	10	108	WF	70		HF	3,313	1,492	Prom.		Exp. L
871	3,376	34	9	115	WF	72		NC	8,913	4,149	Succ.		Exp. L
622	3,215	33	10	108	WF	70		HF	7,620	4,884	Succ.		Exp. L
173	4,568	33	7	162	WF	68		NC	953	391	Succ.		Exp. L
180	1,311	31.5	32	87	WF	73		JS	812	53	Prom.		RW
908	4,626	30	17	133	WF	65		HF	1,179	596	Succ.		Exp. L
875	3,911	15.5	46	154	WF	69		NC	1,072	387	Succ.		Exp. L
901	3,921	14	80	149	WF	71		HF	2,084	707	Prom.		Exp. L
875	3,911	15.5	46	158	WF	69		NC	3,984	1,026	Prom.		RW
412	3,238	21	19	127	WF	60		NC	1,082	446	Succ.		Exp. L
538	3,346	21	22	123	WF	60		NC	365	211	Succ.		Exp. L
	3,215	33											
	3,376	33.5											
	3,911	15.5											
	3,921	13.6											
	4,560	32.08											
	1,640-2,065	29											
	935-1,575	31.5											
	2,132-3,464	12											
	2,886-3,149	14-20											
1,200	2,100	12.8	2,965	108	Prim.	57		NC	13,000	8,000	Succ.	Yes	FW
1,200	2,100	12.8	2,965	108	SS	57	10	HF	1,000	500	Disc.	No	P (Exp. UL)
300-15,000	2,500-2,700	25	175	100	HW	10-90	10-90	JS	300	280	TETT	Good	FW
300-15,000	2,500-2,700	25	175	100	WF	10-90	10-90	JS	320	320	Prom.	Good	FW
300-15,000	2,500-2,700	25	175	100	HW	10-90	10-90	HF	470	465	Succ.	Good	FW
300-15,000	2,500-2,700	25	175	100	HW	10-90	10-90	HF	200	200	Succ.	Good	FW
300-15,000	2,500-2,700	25	175	100	WF	10-90	10-90	HF	630	615	Succ.	Good	FW
5,000	4,000	25.7	10	185	Prim.	82		HF			TETT		P
8,000-15,000	3,440	15.6	100-150	158	Prim.	70		NC	190	190	Succ.		P (FW)
8,000-15,000	3,440	13.5	550	158	Prim.	80		HF	165	165	Prom.		P (Exp. L)
	3,450	15.6											
	3,450	17											
	3,120	15.6											
1,600	550	22	350	100	Prim.	62	15	NC	190,000	190,000	Succ.	Yes	FW
1,600	350	22	350	100	Prim.	60	15	NC			Succ.	Yes	FW
								HF					

PRODUCING EOR PROJECTS OUTSIDE US AND CANADA (CONTINUED)

Type and operator	Operator	Type project	Field	Start date	Area, acres	No. wells prod.	No. wells inj.	Pay zone	Formation	Porosity, %
Trinidad										
Parrylands	New Horizon	Steam	Block E	7/01	744	6	0	Forest Sands	S	36
Forest Reserve	Petrotrin	CO_2 immiscible	Area 2102	6/76	58	6	2	Forest Sands	S	32
Forest Reserve	Petrotrin	CO_2 immiscible	Area 2121	1/74	29	2	2	Forest Sands	S	30
Forest Reserve	Petrotrin	CO_2 immiscible	Area 2124	1/86	184	3	1	Forest Sands	S	31
Forest Reserve	Petrotrin	CO_2 immiscible	EOR 34 - Cyclic	84	NA	11	0	Forest/MLE	S	29
Oropouche	Petrotrin	CO_2 immiscible	Oropouche	6/90	175	4	3	Retrench	S	30
Oropouche	Petrotrin	CO_2 immiscible	EOR 44	6/90	175	2	0	Retrench	S	30
Guapo	Petrotrin	Steam	Guapo	8/76	400	80	12	Cruse E & F	S	25
Point Fortin	Petrotrin	Steam	Cruse E	2/86	66	17	7	Cruse E	S	31
Point Fortin	Petrotrin	Steam	Parrylands	7/81	86	25	6	Forest	S	30
Point Fortin	Petrotrin	Steam	Parrylands E	7/81	86	16	7	Forest	S	30
Forest Reserve	Petrotrin	Steam	Phase I Cyclic	8/76	58	8	0	Forest Sands	S	31
Forest Reserve	Petrotrin	Steam	Phase I West	12/88	23	3	10	Forest Sands	S	30
Forest Reserve	Petrotrin	CO_2 immiscible	EOR 33	6/76	58	2	0	Forest	S	32
Forest Reserve	Petrotrin	CO_2 immiscible	EOR 26	1/74	29	0	0	Forest	S	30
Forest Reserve	Petrotrin	CO_2 immiscible	EOR 4	1/86	184	4	0	Cruse	S	31
Forest Reserve	Petrotrin	Steam	EOR 32	8/76	58	6	0	Forest Sands	S	31
Forest Reserve	Petrotrin	Steam	EOR 43	12/88	23	4	0	Forest Sands	S	30
Forest Reserve	Petrotrin	Steam	EOR 45	9/94	40	13	0	Forest Sands	S	30
Point Fortin	Petrotrin	Steam	Cruse E Pilot	2/86	66	18	5	Cruse E	S	31
Palo Seco	Petrotrin	Steam	North Palo Seco	10/69	300	150	40	Lower Morne L'Enfer	S	28
Palo Seco	Petrotrin	Steam	Central Los Bajos	2/74	190	110	16	Lower Morne L'Enfer	S	28
Forest Reserve	Petrotrin	Steam	Forest Reserve UMLE Pilot	3/04	20	12	3	UMLE	S	32
Forest Reserve	Petrotrin	Steam	Forest Reserve UMLE Exp.	3/06	23	13	2	Forest Reserve UMLE Exp.	S	32
Turkey										
Batman	TPAO	CO_2 immiscible	Bati Raman	3/86	12,890	212	69	Garzan	LS	18
Venezuela										
Maturin, Campo Mulata	PDVSA E&P	HC Miscible	Carito Central	12/96	12,000	45	10	NARICUAL	S	8-20
Maturin, Campo Mulata	PDVSA E&P	HC Miscible	Carito Oeste	11/97	9,500	26	5	NARICUAL	S	10-20
Maturin, Campo Furrial	PDVSA E&P	HC Miscible/Water	Furrial	8/98	36,769	102	43	NARICUAL	S	15
Anzoategui	PDVSA E&P	Steam	Bare (F.O.)	3/85	16,452	55	48	U1,3(YAC.MFB-53)	US	31.9
Anzoategui	PDVSA E&P	Steam	Bare (F.O.)	3/87	8,066	66	65	U2,3(YAC.MFB-23)	US	28.6
Anzoategui	PDVSA E&P	Steam	Arecuna (F.O.)	2/85	1,668	5	5	5	US	30.7
Anzoategui	PDVSA E&P	Steam	Arecuna (F.O.)	12/83	1,544	15	15	T(YAC.MFA-52)	US	30.6
Campo Cerro Negro	PDVSA E&P	Steam	B.E.P.-Cerro Negro	1984	49,090	186		Morichal-Memb.	S	35
Campo Jobo	PDVSA E&P	Steam	Jobo	12/69	25,410	88		Jobo Member	S	31
Campo Jobo	PDVSA E&P	Steam	Jobo-P.E.T.C.	8/85	267	17		Morichal	S	30
Campo Jobo	PDVSA E&P	Steam	Jobo	12/69	34,099	301		Morichal	S	30
Campo Pilon	PDVSA E&P	Steam	West Pilon	12/69	1,065	8		Oficina-1	S	31
Zulia	PDVSA E&P	Steam	Bachaquero Lago	12/80	343	2		Bachaquero Superior	S	23
Zulia	PDVSA E&P	Steam	Lagunillas Lago	2/71	9,343	522	2	Bachaquero	S	34
Zulia	PDVSA E&P	Steam	Tia Juana	2/70	1,692	25		Lagunillas Inferior	S	31
Zulia	PDVSA E&P	Steam	Lagunillas	4/65	420	59		U.L.H.	S	35
Zulia	PDVSA E&P	Steam	Lagunillas	8/64	76	7		L.L.	S	33.7
Zulia	PDVSA E&P	Steam	Lagunillas	7/67	618	54		U.L.H.	S	35
Zulia	PDVSA E&P	Steam	Lagunillas	1/70	3,025	147		L.L.	S	33.7
Zulia	PDVSA E&P	Steam	Lagunillas	4/70	2,565	220		U.L.H.	S	35
Zulia	PDVSA E&P	Steam	Lagunillas	8/70	2,114	175		U.L.H.	S	35
Zulia	PDVSA E&P	Steam	Lagunillas	11/79	3,101	261		L.L.	S	33.7
Zulia	PDVSA E&P	Steam	Lagunillas	10/80	3,565	297		U.L.H.	S	35
Zulia	PDVSA E&P	Steam	Bachaquero	11/84	7,795	640		Post-Eocene	S	33.5
Zulia	PDVSA E&P	Steam	East Tia Juana	4/59	341	32		L.L.	S	33.5
Zulia	PDVSA E&P	Steam	East Tia Juana	2/61	35	7		L.L.	S	38.1
Zulia	PDVSA E&P	Steam	East Tia Juana	9/64	411	36		L.L.	S	38
Zulia	PDVSA E&P	Steam	East Tia Juana	5/68	2,755	201		L.L.	S	38.1
Zulia	PDVSA E&P	Steam	East Tia Juana	8/68	3,218	250		L.L.	S	38.1
Zulia	PDVSA E&P	Steam	East Tia Juana	12/68	1,961	168		L.L.	S	38
Zulia	PDVSA E&P	Steam	East Tia Juana	3/69	1,768	145		L.L.	S	38.1
Zulia	PDVSA E&P	Steam	East Tia Juana	8/69	1,642	148		L.L.	S	38.1
Zulia	PDVSA E&P	Steam	East Tia Juana	12/69	392	36		L.L.	S	38.1
Zulia	PDVSA E&P	Steam	East Tia Juana	11/74	1,848	135	21	L.L.	S	38.1
Zulia	PDVSA E&P	Steam	East Tia Juana	9/86	1,380	144		L.L.	S	36
Zulia	PDVSA E&P	Steam	Main Tia Juana	10/63	867	82		L.L.	S	38.1
Zulia	PDVSA E&P	Steam	Main Tia Juana	6/66	144	15		L.L.	S	38.1
Zulia	PDVSA E&P	Steam	Main Tia Juana	7/67	1,291	114		L.L.	S	38.8
Zulia	PDVSA E&P	Steam	Main Tia Juana	7/67	1,500	134		L.L.	S	38.1
Zulia	PDVSA E&P	Steam	Main Tia Juana	10/67	2,323	197		L.L.	S	38.1
Zulia	PDVSA E&P	Steam	Main Tia Juana	10/67	1,286	86		L.L.	S	38.1

TABLE E

Perme-ability, md	Depth, ft	Gravity, °API	Oil, cp	Oil, °F.	Prev. prod.	Satur. % start	Satur. % end	Proj. matur.	Tot. prod., b/d	Enh. prod., b/d	Proj. eval.	Profit	Project scope
750	850-1,200	16-18	5,000	97	Prim.	80		JS	100		TETT		LW
175	3,000	19	16	120	Prim.	56		HF	43	43	Succ.	Yes	Exp. L
150	2,600	17	32	120	Prim.	60		HF	0	0	Prom.		Exp. L
300	4,200	25	6	130	WF	44		TS	78	78	Prom		Exp. L
150	2,025	17	11-145	120	Prim.	-		C	15	15	Prom	Yes	Exp. L
36	2,400	29	5	120	Prim.	53	48	HF	32	32	Prom.		P
36	2,400	29	5	120	Prim.	53		C	15	15	Prom.	No	P
300	2,400	11	5,500	100	Cyclic	75		HF	792	792	Succ.	Yes	RW
95	1,400	17	175	110	Prim.	58	18	HF	325	325	Prom.		P
500	1,100	11	5,500	104	Prim.	75	20	HF	89	89	Succ.	Yes	RW
500	1,100	11	5,000	105	Prim.	75		HF	235	235	Succ.	Yes	RW
205	1,200	19	32	105	Prim.	57	15	NC	69	69	Disc.	No	RW
430	1,500	17	160	105	Prim.	67	25	JS	76	76	Disc.	No	RW
175	3,000	19	16	120	Prim.	56		C	26	26	Succ.	Yes	Exp. UL
150	2,600	17	32	120	Prim.	60	NA	Term.	0	0	Prom.	Yes	Exp. UL
300	4,200	25	6	130	WF	44		C	176	176	Succ.	Yes	Exp. L
205	1,200	19	32	105	Prim.	57		C	0	0	Disc.	No	Exp. UL
430	1,500	17	160	105	Prim.	67		C	17	17	Disc.	No	Exp. UL
270	1,100	14	250	110	Prim.	70		C	50	50	Disc.	No	Exp. UL
250	1,400	17	175	110	Prim.	58		HF	254	254	Succ.	Yes	P
250	1,700	16	550	110	Prim.	70		HF	1,200	1,200	Succ.	Yes	RW
250	1,500	16	550	105	Prim.	70		HF	800	800	Succ.	Yes	RW
300	1,700	13	550	100	Prim.	75		JS	307	307	Prom.		P
300	1,700	13	550	100	Prim.	75		JS	633	633	Prom		RW
58	4,265	13	592	129		78		NC	7,000	7,000	Succ.	Yes	FW
10-1,000	13,000-14,500	21 - 33	0.1 - 0.5	290	Prim.	80		JS	150,000	80,000	Succ	yes	FW
10-1,000	13,000-14,500	24 - 36	0.1 - 0.5	290	Prim.	80		JS	80,000	45,000	Succ	yes	FW
600	13,000-14,300	26	0.5	290	WF	75		JS	410,000	41,000	Prom	yes	FW
6,600	2,650	9.3	376	131	Prim.	88	75	HF	65,000	20,000	Succ.	Yes	RW (Exp. L)
5,000	3,050	9.2	351	136	Prim.	83	75	HF	4,500	500	Succ.	Yes	RW (Exp. L)
5,800	2,850	10	370	135	Prim.	82	74	NC	0	0	Disc.	No	P (Exp. UL)
4,500	3,150	9.8	560	140	Prim.	80	72	NC	0	0	Prom.	Yes	RW
10,000	2,000	8.5	5,500	125	Prim.	80		HF	650	400	Succ.	Yes	P (Exp. L)
2,500	3,260	13.5	138	130	Prim.	80		HF	14,101	0	Succ.	Yes	FW
5,000	3,600	9	1,952	132	Prim.	85		NC	1,530	0	Succ.	Yes	P (Exp. L)
5,000	3,600	9	1,952	132	Prim.	85		JS	5,607	514	Succ.	Yes	FW
8,000	3,350	10	727	139	Prim.	82		JS	23,912	0	Succ.	Yes	RW
1,500	3,400	14	185	135	Prim.	85		JS	32,517	17,997	Succ.	Yes	P (Exp. L)
4,000	2,690	12	600	128	Prim.	84		HF	44,219	31,135	Succ.	Yes	FW
1,250	2,537	15	93	119		72		HF	5,916	3,815	Succ.	Yes	P(Exp. L)
	2,300	11.4	3,500	117	Prim.	75	44	NC	2,318	2,318	Succ.	Yes	FW
	2,850	15.2	2,500	125	Prim.	80	50	NC	257	257	Succ.	Yes	FW
	2,300	11.4	3,500	117	Prim.	75	46	NC	2,629	2,629	Succ.	Yes	FW
	2,850	15.2	2,500	122	Prim.	87	54	HF	2,675	2,675	Succ.	Yes	FW
	2,300	11.8	7,000	115	Prim.	75	54	HF	21,016	21,016	Succ.	Yes	FW
	2,300	11.4	3,500	118	Prim.	75	63	HF	5,872	5,872	Succ.	Yes	FW
	2,850	15	580	126	Prim.	87	66	HF	4,399	4,399	Succ.	Yes	FW
	2,300	11	20,000	125	Prim.	75	63	HF	19,920	19,920	Succ.	Yes	FW
575	2,000	13	500	117	Prim.	84.5	40	JS	15,190	15,190	Succ.	Yes	FW
2,500	1,500	12	1,000	108	Prim.	85	48	HF	470	470	Succ.	Yes	FW
1,300	1,746	13.6	13,000	100	Prim.	85	45	NC	171	171	Succ.	Yes	P
3,000	1,250	12	3,000	104	Prim.	85	65	HF	489	375	Succ.	Yes	FW
	1,200	12	750	104	Prim.	85	64	HF	4,806	4,139	Succ.	Prom.	FW
3,000	872	12	5,000	104	Prim.	81	74	HF	7,778	7,257	Succ.	Yes	FW
	1,250	12	7,500	106	Prim.	85	67	HF	6,415	6,052	Succ.	Yes	FW
780	1,700	12.1	2,000	111	Prim.	85	67	HF	4,233	3,636	Succ.	Yes	FW
1,300	1,250	10	12,000	102	Prim.	85	77	HF	5,316	5,316	Succ.	Yes	FW
	1,000	11.1	10,000	95	Prim.	85	72	HF	963	963	Succ.	Yes	FW
780	1,597	12	1,000	111	Prim.	85	46	HF	2,100	2,100	Succ.	Yes	FW
1,000-4,000	760	9-11	5,000-30,000	110	Prim.	85	82	HF	6,857	6,857	Succ.	Yes	FW
1,400	1,750	13.1	750	113		85	57	NC	842	842	Succ.	Yes	FW
675	1,250	13.1	1,300	104	Prim.	85	65	NC	120	120	Succ.	Yes	FW
675	1,209	13.1	5,000	123	Prim.	85	61	HF	3,412	3,412	Succ.	Yes	FW
1,000	1,400	13.1	1,000	110	Prim.	85	65	HF	4,224	4,224	Succ.	Yes	FW
1,000	1,746	13.1	4,100	110	Prim.	85	62	HF	4,264	3,878	Succ.	Yes	FW
1,000	1,746	13.1	1,200	110	Prim.	85	76	HF	1,129	1,129	Succ.	Yes	FW

Moving caustic injection point improves crude unit operations

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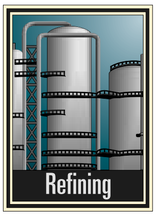


Saudi Aramco was experiencing serious fouling and corrosion in the second preheat train in the crude unit in its Yanbu refinery. The problems were due to underdeposit, inorganic deposit, and high-temperature sulfide corrosion, which led to pressure buildup and tube leaks in the crude unit.

Relocating the caustic injection point to upstream of the crude heater allowed the refiner to overcome heat exchanger fouling and solve maintenance problems.

On average, this project is saving $80,000/year in maintenance costs. The cost avoidance of dumping diesel to fuel oil is about $1.5 million/year.

This article discusses the problems faced after the relocating project and lessons learned.

Background

Saudi Aramco's Yanbu refinery is a hydroskimming refinery with a capacity of 235,000 b/d. Crude passes through three preheat stages (series of heat exchangers) before entering the crude heaters. After the first preheat stage, water is added to the preheated crude before it enters the desalters.

A 3°Baume (Be) caustic solution is injected upstream of the desalters to neutralize acids formed. Also, a 3°Be caustic is injected downstream of the desalters for corrosion control.

Since Yanbu started up in 1983, the second preheat stage exchangers had a history of active corrosion and fouling problems. Aramco's Consultant Services Department (CSD) strongly recommended implementing a best practice, which was to relocate the downstream caustic injection to upstream of the crude heaters from downstream of the desalters to eliminate corrosion and fouling in the second preheat exchangers.

Process overview

The crude distillation process (Unit V04) involves the crude charge flowing through preheating, desalting, charge heating, crude column distillation, and naphtha fractionation. The crude unit consists of two identical preheat trains (A and B).

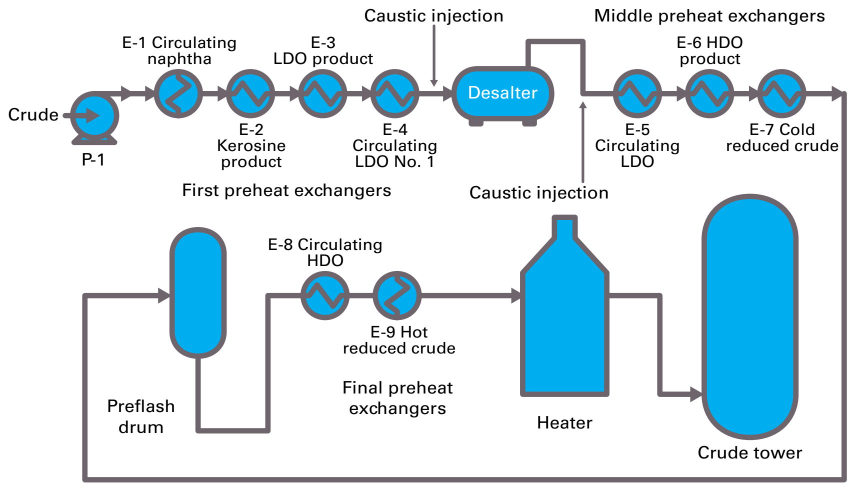
Fig. 1 shows a flow diagram of the Yanbu refinery crude distillation unit.

Crude charge passes through the first-stage preheat train, which is a series of four heat exchangers:

- E-1. Crude-circulating naphtha

YANBU CRUDE DISTILLATION UNIT

Fig. 1



exchanger.

- E-2. Crude-kerosine product exchanger.
- E-3. Crude-light diesel oil (LDO) product exchanger.
- E-4. Crude-circulating LDO No. 1 exchanger.

After the first preheat train, crude flows to the desalters at about 120-125° C. and is mixed with wash water before entering the desalters. From the desalters, crude passes through the second-stage preheat train that heats the crude to its flash temperature in a series of three heat exchangers:

- E-5. Desalted crude-circulating LDO No. 2 exchanger.
- E-6. Desalted crude-heavy diesel oil (HDO) product exchanger.
- E-7. Desalted crude-cold reduced crude exchanger.

Liquid from the flash drum, V2, is pumped in the flash drum bottoms pump, P2, to the final preheat section:

- E-8. Desalted crude-circulating HDO exchanger.
- E-9. Desalted crude-hot reduced crude exchanger.

Preheated crude finally enters crude charge heaters, H-1A and B, where it is heated to crude column flash-zone requirements. The heater outlet temperature is controlled at 375° C.

Caustic injection

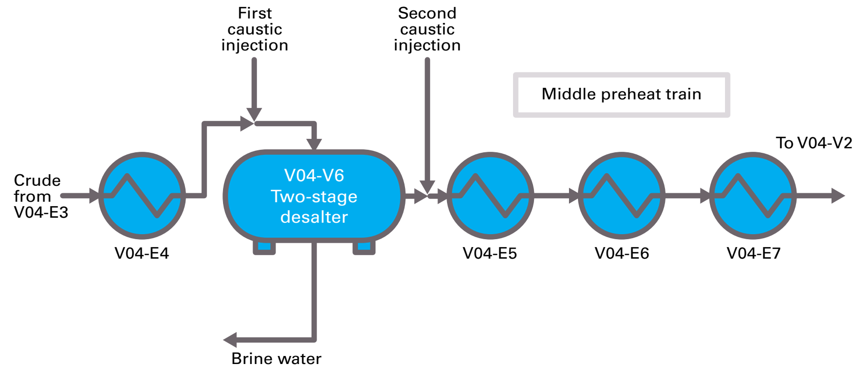
After the first preheat section, water is added to and thoroughly mixed with the preheated crude using a preset mixing valve before it enters the first-stage desalter, V6A. Crude leaves the desalter and is further mixed with fresh water before entering the second-stage desalter, V6B.

The 3°Be caustic is injected upstream of the desalters to neutralize acids formed during the hydrolysis of salt. Caustic injection is controlled to maintain a pH value of 6-7 in the brine water effluent. The 3°Be caustic is also injected downstream of the desalters for corrosion control and to control the chloride content in the crude distillation tower overhead.

Fig. 2 shows the caustic injection locations.

Caustic injection locations

Fig. 2



Fouling, corrosion problems

Aramco had observed, since the refinery started up in 1983, that the middle preheat exchangers V04-E5, E6, and E7 had active corrosion and fouling problems, caused by underdeposit, inorganic deposits, and high-temperature sulfide corrosion, which lead to pressure buildup and tube leaks.

Underdeposit corrosion products are activated mainly by elevated temperatures on the inlet shell-sides of the exchangers, which lead to underdeposit corrosion due to partial vaporization of the water and light ends in the crude. The high temperature of the crude passing through the second preheat train is another factor that can accelerate such fouling.

Because Arabian Light crude has a high sulfur content of 1.5-2.0%, and due to high operating temperatures, the environment is ideal for

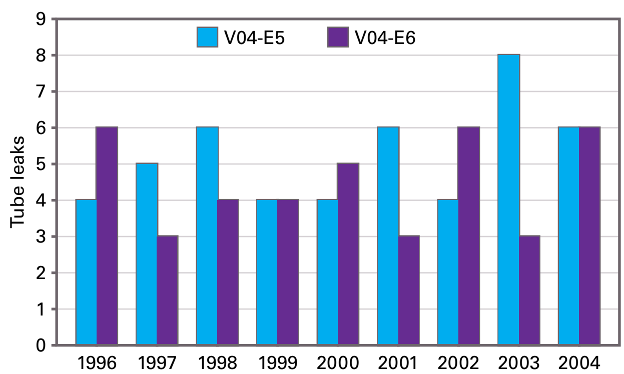
V04-E6 flow calculation

Table 1

Flow	cu m/hr	b/d
HDO normal flow to both preheat trains	110	16,610
HDO flow if one train is isolated (E6A or E6B)	77	11,627
HDO dumping to fuel oil	33	4,983

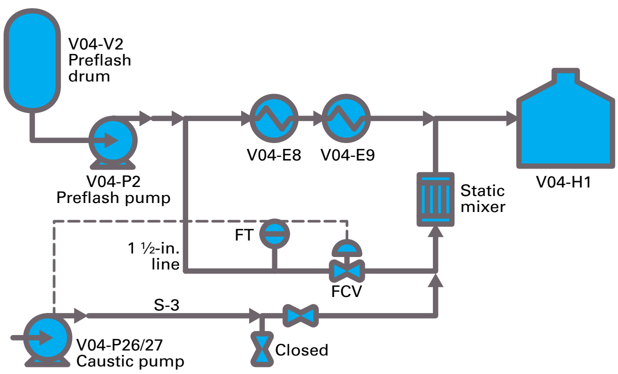
Exchanger leaks

Fig. 3



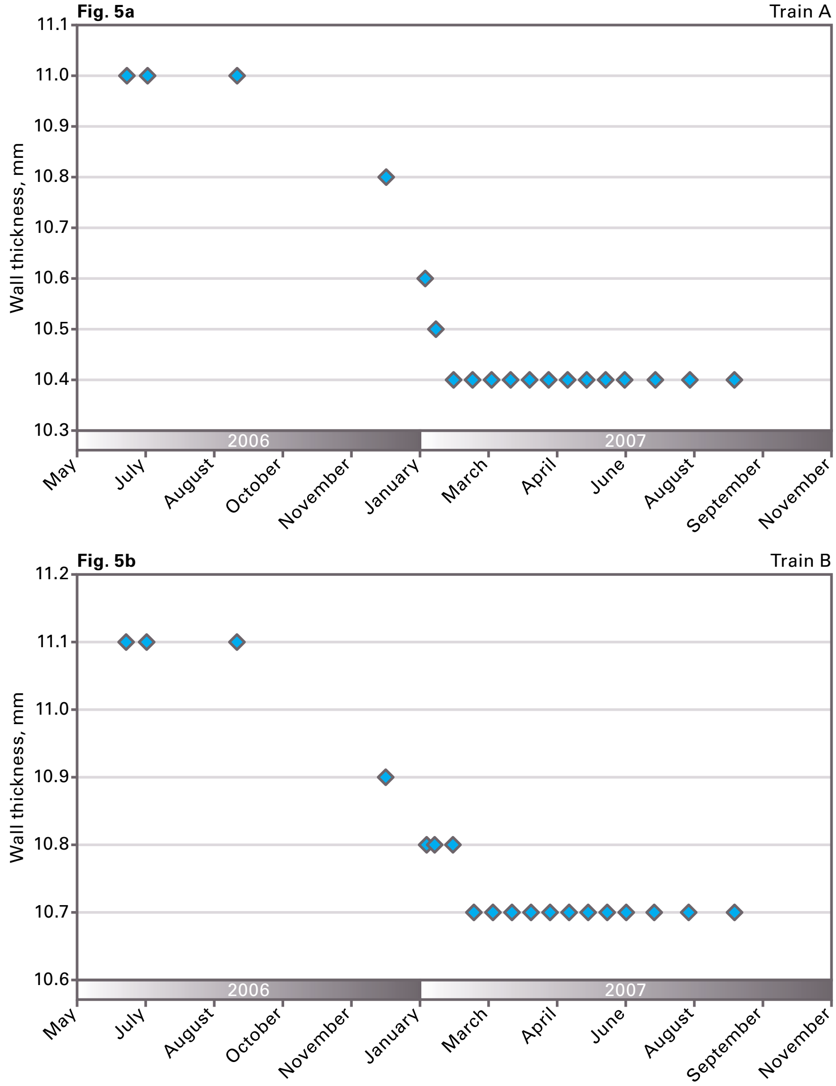
New caustic injection configuration

Fig. 4



CAUSTIC CORROSION

Fig. 5



COST OF DUMPING HDO

Table 2

Average diesel cost, $/bbl	75
Average fuel oil cost, $/bbl	50
Difference, $/bbl	25
Isolation time, days/year	12
Loss, $ million/year	1.5

NEW CAUSTIC INJECTION THINNING

Table 3

Date	– Min. wall thickness, mm – Location 1	Location 2
June 18, 2006	11.0	11.1
July 3, 2006	11.0	11.1
Sept. 6, 2006	11.0	11.1
Dec. 24, 2006	10.8	10.9
Jan. 22, 2007	10.6	10.8
Jan. 23, 2007	10.6	10.8
Jan. 29, 2007	10.5	10.8
Feb. 11, 2007	10.4	10.8
Feb. 26, 2007	10.4	10.7
Mar. 12, 2007	10.4	10.7

high-temperature sulfur corrosion.

The research and development department's analysis of inorganic deposits inside the tubes of V04-E7 showed that about 88 wt % of the plugging material was the iron sulfide corrosion products pyrite and pyrrhotite, 9 wt % was water soluble salts halite-NaCl, and 3 wt % was calcium carbonate. These inorganic deposit materials are the major contributors of fouling inside the tube, which led to a pressure buildup.

The high temperature of crude passing through the second preheat train is another factor that accelerates fouling. A two-stage desalter after the first preheat train was designed to minimize salt in the feed. The outlet design for salt is less than 1 lb/1,000 bbl. This target was not attainable due to low desalter efficiency, caused by an inadequate water wash rate and a low desalter residence time.

The water wash injection, according to industrial best practices, should be 3-5 vol % to assure that the required salts are dissolved compared with the existing injection rate, which is around 2.9 vol %. A correct desalter residence time is also important in ensuring that no water carryover occurs. The calculated residence time of the Aramco desalter was 11.5 min at 235,000 b/d, which is less than the design rate of 15 min at 170,000 b/d.

We concluded that downstream caustic injection acts as a catalyst for fouling and underdeposit corrosion, which increases the pressure drop and leakage in the middle preheat exchangers.

Middle preheat exchangers

We found that most of the tube leaks were in the top portion of the bundle, especially for V04-E5 and V04-E6. This is due to the high heat flux at that location.

Fig. 3 shows the number of tube leaks for V04-E5 and V04-E6.

For V04-E7, most of the problems associated with these exchangers were uniform thinning, localized attack, and erosion corrosion, according to Aramco's CSD.

The inspection records showed that the V04-E5 and V04-E6 tube bundle metallurgy was upgraded for both trains to 12% Cr steel from carbon steel and 5 Cr-1/2 Mo due to the high frequency of tube failures. Only three exchangers for V04-E7 were upgraded to 5 Cr-1/2 Mo while the others are carbon steel.

CSD confirmed that the original carbon provided a satisfactory service life of about 20 years and upgrading the subject tube bundles to 5 Cr-1/2 Mo would not fully eliminate the erosion-corrosion problems.

Caustic injection relocation

CSD recommended relocating the downstream caustic injection to 66 m upstream of the V04H1A/B heater from its previous location downstream of the desalters. This would enhance overhead corrosion control of chlorides and would eliminate the corrosion and fouling problem in the second preheat exchangers.

The design included adding a crude slipstream to the caustic stream before it is injected in the 14-in. heater charge line to eliminate water vaporization and caustic deposition. In addition, an interlock system would trip the caustic pumps if the crude slipstream flow is low.

The premixed caustic injection point is 66 m upstream of the crude charge heater passes. This is to allow the premixed caustic to mix well with the bulk crude.

In addition, Monel 400 was used to construct the piping downstream of the crude slipstream-caustic mixing point. The quill and the static mixer were also constructed of Monel 400. The new caustic injection point was started up on May 2006.

Fig. 4 shows the new caustic injection configuration.

Post relocation project

Aramco observed that frequent fouling of the second preheat exchangers was eliminated. Testing and inspection of eight desalted crude heat exchangers V04-E5 and E6 were completed on July 2007. An initial visual inspection revealed that all components were in good condition without any significant mechanical damage.

A 100% magnetic particle inspection, conducted on the internal weld seems of the shells, channel box, and covers, did not reveal any defects. All exchangers passed initial and final hydrostatic tests.

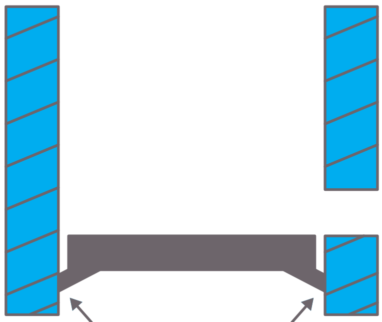
Aramco experienced major savings due to this project. Before, on average, 10 exchangers/year were fouled and leaked. Mechanical cleaning, hydrotesting, and maintenance labor cost $8,000/exchanger. On average, this project saves $80,000/year in maintenance costs.

Furthermore, this project prevented the frequent isolation of V04-E6 A/B. The isolation of this exchanger resulted in the dumping of HDO product to the fuel oil stream, reducing the production of diesel (Table 1).

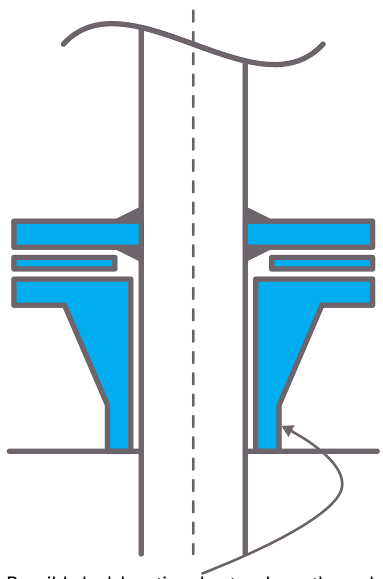
On average, the V04-E6 isolation occurred 10 times annually, with an average of 3 days of maintenance work. The cost of dumping HDO to fuel oil is $1.5 million/year (Table 2).

On average, this relocation project is saving $1.8 million/year.

TRAIN A INJECTION QUILL ASSEMBLY Fig. 6



TRAIN B INJECTION QUILL ASSEMBLY Fig. 7



Corrosion

After relocating the caustic injection on May 2006, inspection data at the new caustic injection locations revealed unacceptable corrosion rates in the 14-in. crude lines upstream of the heaters for Trains A and B.

Table 3 and Fig. 5 show that the estimated localized corrosion rates were 0.6 mm/5 months for Train A (at the bottom) and 0.4 mm/5 months for Train B (at the top).

CSD, P&CSD, and Yanbu plant personnel conducted a root-cause analysis to focus on potential causes and actions necessary to minimize corrosion. This included examining the detailed inspection data (ultrasonic testing, radiographs, scans, and infrared), as well as design, fabrication, and operational parameters.

The parties concluded that the damage mechanisms for each train were different and most likely scenario for the attack was:

- Metal losses in the 14-in. crude lines were due to general corrosion attack from the caustic, which attacked the pipe wall before it was diluted with crude. This would explain the highly localized corrosion seen immediately downstream of the injection point in the 6 o'clock position for Train A and in the 12 o'clock position for Train B.
- For Train A, the parties suspected that there are leaks of partially undiluted caustic on the 14-in. carbon steel line from the root of fillet welds of the quill end plate that is causing corrosion (Fig. 6). Infrared surveys showed localized areas of much lower temperatures.
- For Train B, the parties suspected that improper mixing was allowing some of the caustic to drift upwards to the crude piping, leading to localized attack. The end plate weld in this case appeared to be solid and intact. Also,

we cannot be certain if there could be a small leak in the flange weld that could allow top of the line corrosion (Fig. 7).

Further work

The investigation team believes that the leak on the quill plugged itself. In the meantime, Aramco is conducting biweekly ultrasonic testing scanning on the new injection points to ensure integrity of the crude line. Furthermore, Aramco will take the first coming shutdown opportunity to visually inspect the injection quill for replacement or upgrade. ✦

The author

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Field work cuts threat to suspended pipeline

Li Chang-jun
Zhu Xiao-lan
Liao Ke-xi
Liu En-bin
Southwest Petroleum University
Chengdu, China

Pipelines

Field experiments have reduced the likelihood of damage or failure of a suspended gas pipeline span as a result of pigging. The potential displacement and vibration caused by pigging pose particular problems in suspended spans. Great enough displacement or vibration could create deformation of the line or failure.

The Fujiang pipeline bridge on the north main line of the Sichuan natural gas transmission network lies about 200 m upstream of the main Fujiang river bridge. Fig. 1 shows the structure of the Fujiang pipeline bridge. The bridge uses two 50-m towers, with the pipeline suspended by diagonal cables. The main pipe span measures 320 m. The two spans running between each tower and the riverbank measure 150 m.

The pipeline consists of 720-mm OD, 12-mm WT steel pipe. Diameters of the cables range between 22.5 and 45 mm. The towers used welding construction. The cables alone support the pipeline. The pipeline bends 10 m upward at each tower as temperature compensation. The overall structure is highly flexible.

The liquids encountered during pipeline pigging create particularly heavy loads at the bends, heightening the possibility of leaks and damage.

Fujiang crossing, self-vibration characteristics

Table 1

Direction	Frequency, hz	Period, sec	Amplitude, m/sec²	Damping ratio
Horizontal	0.0821	12. 180	35. 242	0. 098
	0. 107	9. 346	16. 261	0. 080
	0. 150	6. 667	9. 902	0. 078
	0. 193	5. 181	9. 720	0. 062
	0. 257	3. 891	6. 203	0. 057
	0. 281	4. 762	4. 887	0. 018
	0. 386	2. 591	5. 101	0. 013
Vertical	0. 382	2. 618	0. 855	0. 048
	0. 468	2. 137	0. 0261	0. 040
	0. 656	1. 524	0. 0212	0.038
	0. 843	1. 186	0. 0520	0. 034

Vertical vibration displacement during pigging

Table 2

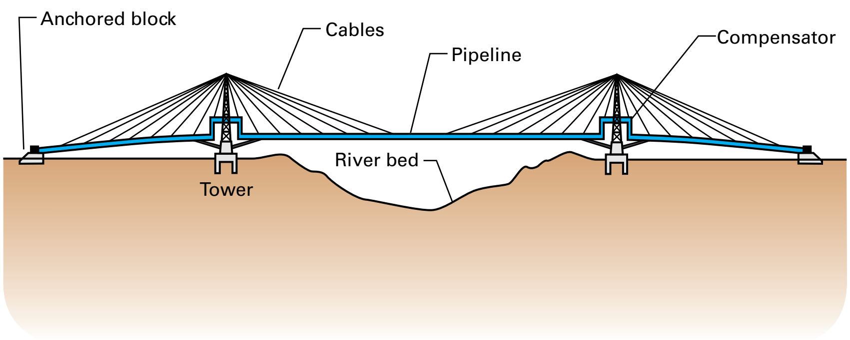
Operating conditions		Position	½ main span (m)	¼ main span (m)	Compensator (m)
1	Transportation pressure, MPa	1.23	0.021	-0.074	0.053
	Flow rate, ×10,000 cu m/day	77			
	Water volume, cu m	0			
	Average pigging speed, m/sec	1.84			
2	Transportation pressure, MPa	1.13	0.094	-0.412	-0.102
	Flow rate, ×10,000 cu m/day	73			
	Water volume, cu m	3			
	Average pigging speed, m/sec	2.01			
3	Transportation pressure, MPa	1.12	0.161	-0.762	-0.616
	Flow rate, ×10, 000 cu m/day	77			
	Water volume, cu m	6			
	Average pigging speed, m/sec	4.08			

This article details both the static and dynamic tests conducted at Fujiang crossing in an effort to find a scientific basis for drafting vibration absorbing measures.

Static tests demonstrated little difference between horizontal and vertical damping ratios and the higher the frequency, the smaller the damping ratio. Dynamic tests showed that the maximum vibration displacement of the Fujiang pipeline crossing did not occur at the middle of the main span, but instead somewhere between the ¼-mark and the middle.

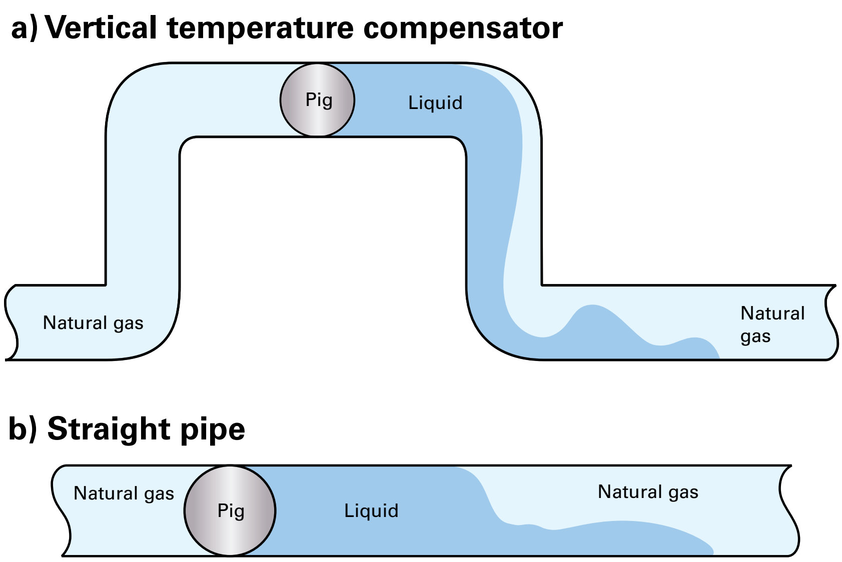
Fujiang suspension pipeline bridge

Fig. 1



Loading during pigging

Fig. 2



Dynamic characteristics

Pigs drive the fluid in front of them, formng slack two-phase flow. Flow patterns and liquid content change dynamically, creating continuous loading change when pigging is under way. Introducing a slack factor determines dynamic loading of the crossing during pigging. Similarity principle and laboratory experiments determined the slack factor (Equation 1).

The change in flow direction at the vertical temperature compensator (Fig. 2a) creates an impact load at the elbow. Momentum theory guides development of a mechanical balance equation (Equation 2), allowing calculation of the impact load.

Friction of the pig and pressure differences between the flow preceding it and the flow following it create changes of velocity in straight-line segments (Fig. 2b). The Hamilton principle guides deduction of the straight-line axial flow, which in turn informs construction of a mechanical balance equation (Equation 3).

As a pig drives the slack fluid through the crossing, it will create an active force and deform the pipe. The deformation will change fluid flow parameters such as liquid-containing rate, speed, and pressure. The change of flow parameters will in turn affect the crossing's vibration properties, displacing the crossing and creating large vibrations. These factors prompted application of a large displacement, minor-strain nonlinearity finite element method to analyze the dynamic characteristics of crossing during pigging.

Ascertaining dynamic characteristics of the crossing during pigging requires prior establishment of basic differential equations regarding the pipeline, cables, and towers. Geometry required assessment of nonlinear factors such as initial internal force at the crossing, rope sag, and equivalent variable cross-section beam dynamics. Analysis assumed that ropes were tensional, not based on compression. The special finite element method guided the setup of basic differential equations.

Boundary constraints of the main components of the crossing structure followed establishment of the fundamental equations of the pipeline, ropes, and towers. These included:

- Anchored block. The displacement and angle deformation of the pipeline at each anchoring block direction equals 0.
- Junction between tower, cables. The Fujiang pipeline crossing featured cable element nodes and tower element nodes with identical displacement and angle deformation, caused by an inability to separate slides between the dragline and the tower top.
- Junction between cables, pipeline. Welding the cable to the pipeline's

junction blocks gave the cable element node and pipeline element node identical displacement and angle deformation.

The crossing's structural properties, geometric nonlinearity, and dynamic loading characteristics allow building a nonlinear finite element model. Equation 4 expresses basic node displacement. Equation 5 shows the finite element's relationship between stress and strain.

The d-Alembert principle allows building the elements' fundamental kinetics equation (Equation 6).

Analyzing the dynamic characteristics of a pipeline bridge suspended by diagonal cable required initial definition of the crossing's incremental kinetics using the Lagrange UL column (Equation 7).

These matrices are typically implicit functions of time and displacement, solvable through adopted subspace iteration, Newton-β, and modified Newton-Raphson methods.

Field testing

Static and dynamic tests measured the Sichuan Jiangyou pipeline bridge's properties. The static test first measured the crossing's self-vibration frequency, amplitude, damping ratio, and the cables' inner force using the environment random stimulation method. Table 1 shows select results of static testing.

Dynamic tests then measured acceleration and vibration parameters at each position. Devices set up at each end of the crossing for compression, water injection, and pig launch and receiving controlled water quantity and pig speed during testing. Testing measured displacement, pipeline inner strain, and cable inner strain in varied operating conditions at each ⅛ increment of the crossing is main span, at the gantry, and at the temperature compensators. Tables 2 and 3 show select dynamic testing results.

Results, analysis

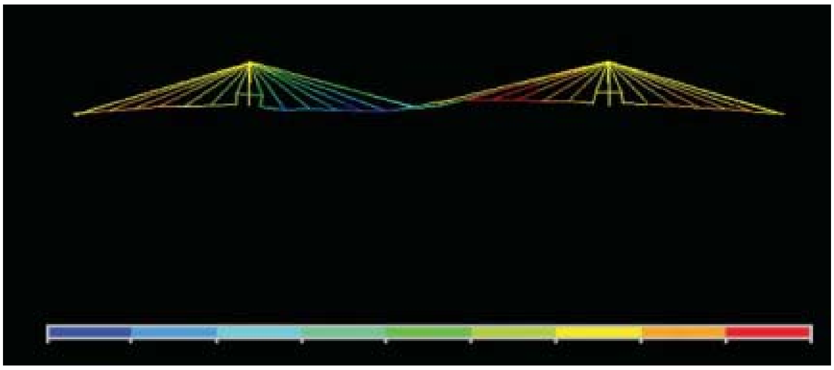
Combined theoretical analysis and field testing simplified the complicated flow in the vertical temperature compensator, yielding slack factor n, which provided a basis to evaluate dynamic loading near the compensator. Using the bridge's initial position as a reference point provided the basis for establishing finite element balance and kinematics equations according to the Lagrange UL column matrix.

The models described in this article, combined with finite element analysis software (ANSYS), simulated and predicted vertical vibration of the Fujiang pipeline crossing during pigging. Maximum displacement of −0.417 m occurred somewhere between the ¼-mark of the main span and the span's middle (Fig. 3).

Table 4 compares measured values from testing with calculated values; finding agreement and validating the vibration absorption theories.

VERTICAL VIBRATION DEFORMATION, M

Fig. 3



CABLE INTERNAL FORCE*

Table 3

No.	Length, m	Diameter, mm	Linear density, ρ, kg/m	Measured fundamental frequency, f_1, hz	Inner force,T, kiloNewton
1	155.450	45	8.260	0.393	123.7
2	136.250	45	8.260	0.450	124.6
3	117.320	42	7.203	0.529	123.7
4	98.816	42	7.203	0.665	124.6
5	81.022	36	5.292	0.837	97.5
6	64.530	36	5.292	1.046	96.5
7	50.642	25.5	2.659	1.517	62.8

*Transportation pressure = 1.2 MPa; flow rate = 840,000 cu m/day; water volume = 0.

VERTICAL VIBRATION DISPLACEMENT DURING PIGGING

Table 4

Position / Operating condition	½ main span Measured	½ main span Calculated	¼ main span Measured	¼ main span Calculated	Compensator Measured	Compensator Calculated
	m					
Water volume, 3 cu m Average pigging speed, 2.01 m/sec	0.094	0.136	0.412	0.417	0.102	0.15

Equations

$$n = 17.45e^{-2.9700V} + 1 \qquad (1)$$

Where n = slack factor, no dimension; v = velocity, m/sec.

$$\sum F = \rho q(\alpha_2 V_2 - \alpha_1 V_1) \qquad (2)$$

Where F = fluid force in all directions, N; ρ = fluid density, kg/m^3, q = volume flow rate, m^3/sec; α_1, α_2 = momentum correction factor, which can be derived through experiments; $V_1 V_2$ = horizontal and vertical velocity, m/sec.

$$\Delta p_{pig} A' - T - \tau A = ma \qquad (3)$$

Where Δp_{pig} = pressure difference between the front and back of the pig, MPa; A' = pig sectional area, m^2; T = friction between pig and pipe, N; τ = friction shearing force in fluid section, N/m^2; m - fluid mass, kg; a = fluid acceleration m/sec^2.

$$\{U\} = \{U_x, U_y, U_z, V_x, V_y, V_z\}^T \qquad (4)$$

Where U_x, U_y and U_z = node displacement; V_x, V_y and V_z = node speed.

$$\{\sigma\} = [D]\{\varepsilon\} \qquad (5)$$

Where [D] = the material's coefficient matrix. If linear, [D] is a constant matrix, otherwise [D] changes as time or displacement changes.

$$[M(t, \{U\})]_i \{\ddot{U}\}_i + [C(t, \{U\})]\{U\}_i + [K(t, \{U\})]_i = [R(t, \{U\})]\{U\}_i \qquad (6)$$

Where $[M(t, \{U\})]_i$ = mass matrix of element i; $[C(t, \{U\})]_i$ = damping matrix of element i; $[K(t, \{U\})]_i$ = stiffness matrix of element i; and $[R(t, \{U\})]_i$ = loading matrix of element i. These matrices are usually functions of time and displacement, making this equation nonlinear.

$$M \cdot \Delta^t\ddot{U} + C \cdot \Delta^t\dot{U} + {}^tK \cdot \Delta^tU = {}^{t+\Delta t}R - {}^tR \qquad (7)$$

Where ${}^tk$, ${}^tC$ = stiffness matrix and damping matrix at time, t; and $\Delta^t\ddot{U}$, $\Delta^t\ddot{U}$, $\Delta^t\dot{U}$, and Δ^tU = acceleration, velocity, and displacement increment during period.

Acknowledgment

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Equipment/Software/Literature

New portable rupture disk installation aid

This new portable rupture disk installation aid—Test-Tel—works with rupture detector Flo-Tel+ to help ensure proper disk installation.

Test-Tel is a low-cost portable tool that helps improve the rupture disk installation process by eliminating the risk of poorly fitted disks or incorrectly wired detection systems. Test-Tel is simple to use, and the maker says the tool guarantees a correct installation the first time. For maintenance managers, the unit helps ensure accurate rupture control and continuous function of the devices by allowing foolproof, noninvasive checking of alarms. It performs a range of rupture disk status tests, confirming the operation of the Flo-Tel+'s detection capabilities and the Test-Tel's battery strength.

Source: **Elfab Ltd.,** Alder Rd., North Shields, Tyne and Wear, NE29 8SD, England

Upgraded unit offers higher separation efficiency

The upgraded Voraxial separator generates approximately 300% more g force than its predecessor. The company says the upgrade translates into higher separation efficiency and increases the flow rate through the Voraxial while decreasing energy and maintenance requirements.

The firm says its unit is a cost effective method to efficiently separate large volumes of solids and liquids for exploration-production and refinery operations. Without needing a pressure drop, the Voraxial provides for separation while decreasing the amount of space, energy, and weight to conduct the separation—all of which are advantages on an offshore platform.

The separator has the ability to produce a real-time, high g centrifugal force to yield a high-purity product or products at a volume of 3 gpm to more than 10,000 gpm. Its technology is scalable and universal in implementation.

Source: **Enviro Voraxial Technology Inc.,** 821 NW 57th Pl., Fort Lauderdale, FL 33309.

Amphibious dredge recovers subsurface oil

The new submersible amphibious Sub-Dredge is designed for subsurface oil recovery. It features a patented 6-in. EDDY pump that incorporates a hydrodynamically built volute along with a precision engineered geometric rotor. The design enables the unit to pump solids at a rate of 300-350 cu yd/hr while maintaining percent solids as high as 60-80% in situ.

Source: **Tornado Motion Technologies LLC,** 15405 Olde Hwy. 80, El Cajon, CA 92021.

Services/Suppliers

Edgo Group,

Amman, Jordan, has appointed Marc Mazen Afyouni group regional director for Libya, Algeria, and Chad. He replaces Maher Jadallah, who is relocating to Amman and will be part of the senior management team responsible for setting strategic policy. Previously, Mazen was employed by Schlumberger, where he worked for 27 years in roles ranging from wireline logging field engineer to his appointment as general manager of Schlumberger's unit in Chad. Mazen will also serve as Camco general manager in Libya. Camco specializes in slickline, cased-hole logging, TCP and wireline perforation, surface well testing, mini-DST, and electronic memory gauges. Its scope of services will be expanded further in 2008 to include open-hole logging and multiphase flow meters. Mazen graduated from the University of Grenoble, France, in 1981.

Afyouni

Edgo is a diversified engineering services company offering oil field services and infrastructure engineering and logistical support in 21 countries.

Transocean Inc.,

Houston, has named Arnaud Bobillier executive vice-president, assets, succeeding Jean Cahuzac, who is leaving the company to pursue another opportunity. Bobillier previously served as senior vice-president of the company's Europe and Africa Unit (EAU). He began his career with a predecessor company in 1980 and has served in various management positions in several countries. Bobillier, based in Houston, holds an engineering degree in fluid mechanics and thermodynamics from the Ecole Superieure des Techniques de l'Ingenieur de Nancy, France. Transocean also named Ricardo Rosa senior vice-president, EAU, replacing Bobillier. Rosa previously was senior vice-president of the company's Asia and Pacific Unit (APU). Prior to that, he served as vice-president and controller and in a variety of international positions in finance for 19 years with Transocean, a predecessor company, and its parent firm. Rosa, based in Paris, graduated from Oxford University with an MA and subsequently qualified as a Chartered Accountant with the Institute of Chartered Accountants in England and Wales. Succeeding Rosa as SVP, APU, is Deepak Munganahalli, based in Singapore. Munganahalli previously served as manager of the company's India Division, which has grown in recent years from one rig to 13 mobile offshore drilling units. He joined a predecessor company in 1991 and has served in various positions of increasing responsibility, including head of operations in Gabon and corporate training manager in Pau, France. Munganahalli is a graduate of the Indian Institute of Technology at Kanpur and Harvard Business School's General Management Program.

Transocean Inc. is the world's largest offshore drilling contractor and the leading provider of drilling management services worldwide.

Statistics

Imports of crude and products

	Districts 1-4		District 5		Total US		
	4-4 2008	3-28 2008	4-4 2008	3-28 2008	4-4 2008	3-28 2008	*4-6 2007
	1,000 b/d						
Total motor gasoline	800	904	107	40	907	944	953
Mo. gas. blending comp.	393	590	86	—	479	590	640
Distillate	161	321	—	1	161	322	259
Residual	368	176	18	140	386	316	530
Jet fuel-kerosine	137	101	66	10	203	111	294
Propane-propylene	180	145	12	24	192	169	69
Other	1,006	754	(98)	(16)	908	738	676
Total products	**3,045**	**2,991**	**191**	**199**	**3,236**	**3,190**	**3,421**
Total crude	**7,750**	**9,009**	**1,162**	**1,274**	**8,912**	**10,283**	**9,804**
Total imports	**10,795**	**12,000**	**1,353**	**1,473**	**12,148**	**13,473**	**13,225**

*Revised.
Source: US Energy Information Administration
Data available in OGJ Online Research Center.

Additional analysis of market trends is available through **OGJ Online**, *Oil & Gas Journal's* electronic information source, at http://www.ogjonline.com.

OIL&GAS JOURNAL online research center.

OGJ crack spread

	*4-11-08	*4-13-07	Change	Change, %
	$/bbl			
SPOT PRICES				
Product value	121.88	85.47	36.41	42.6
Brent crude	108.26	68.07	40.19	59.0
Crack spread	13.62	17.41	–3.78	–21.7
FUTURES MARKET PRICES				
One month				
Product value	123.25	85.60	37.65	44.0
Light sweet crude	109.74	62.58	47.16	75.4
Crack spread	13.51	23.02	–9.51	–41.3
Six month				
Product value	118.17	81.65	36.52	44.7
Light sweet crude	106.57	69.15	37.42	54.1
Crack spread	11.59	12.50	–0.90	–7.2

*Average for week ending.
Source: Oil & Gas Journal
Data available in OGJ Online Research Center.

Purvin & Gertz LNG netbacks—Apr. 11, 2008

Receiving terminal	Algeria	Malaysia	Nigeria	Austr. NW Shelf	Qatar	Trinidad
	Liquefaction plant ($/MMbtu)					
Barcelona	8.49	6.19	7.58	6.07	6.86	7.49
Everett	8.66	6.22	8.23	6.28	6.90	9.00
Isle of Grain	9.88	7.38	9.65	7.26	8.07	9.15
Lake Charles	7.06	4.85	6.79	5.04	5.36	7.79
Sodegaura	6.70	8.42	6.63	8.43	7.68	5.64
Zeebrugge	8.88	6.52	8.14	6.40	7.13	8.15

Definitions, see OGJ Apr. 9, 2007, p. 57.
Source: Purvin & Gertz Inc.
Data available in OGJ Online Research Center.

Crude and product stocks

District	Crude oil	Motor gasoline Total	Motor gasoline Blending comp.[1]	Jet fuel, kerosine	Fuel oils Distillate	Fuel oils Residual	Propane-propylene
	1,000 bbl						
PADD 1	14,818	60,102	33,108	8,415	31,833	13,750	2,316
PADD 2	65,058	51,762	17,670	7,556	29,077	1,292	8,625
PADD 3	167,130	72,436	35,199	12,890	30,092	17,694	13,800
PADD 4	14,181	6,157	1,864	2,924	2,924	252	[1]696
PADD 5	54,829	30,811	22,964	9,139	12,101	6,270	—
Apr. 4, 2008	**316,016**	**221,268**	**110,805**	**38,510**	**106,027**	**39,258**	**25,437**
Mar. 28, 2008	**319,164**	**224,710**	**113,610**	**38,067**	**109,720**	**39,736**	**24,897**
Apr. 6, 2007[2]	**333,399**	**199,725**	**92,250**	**40,789**	**118,122**	**39,352**	**25,767**

[1]Includes PADD 5. [2]Revised.
Source: US Energy Information Administration
Data available in OGJ Online Research Center.

Refinery report—Apr. 4, 2008

District	Refinery operations: Gross inputs	Refinery operations: Crude oil inputs	Refinery output: Total motor gasoline	Jet fuel, kerosine	Fuel oils Distillate	Fuel oils Residual	Propane-propylene
	1,000 b/d		1,000 b/d				
PADD 1	1,155	1,184	1,688	100	398	112	55
PADD 2	2,977	2,957	2,246	201	879	48	196
PADD 3	7,201	7,035	3,203	692	1,976	241	713
PADD 4	559	554	267	27	182	14	[1]125
PADD 5	2,711	2,619	2,492	421	555	195	—
Apr. 4, 2008	**14,603**	**14,349**	**8,896**	**1,441**	**3,990**	**610**	**1,089**
Mar. 28, 2008	**14,361**	**14,207**	**8,608**	**1,505**	**3,856**	**705**	**1,070**
Apr. 6, 2007[2]	**15,425**	**15,072**	**8,531**	**1,388**	**4,239**	**688**	**991**
	17,588 operable capacity		**83.0% utilization rate**				

[1]Includes PADD 5. [2]Revised.
Source: US Energy Information Administration
Data available in OGJ Online Research Center.

OGJ GASOLINE PRICES

	Price ex tax 4-9-08	Pump price* 4-9-08	Pump price 4-11-07
	¢/gal		
(Approx. prices for self-service unleaded gasoline)			
Atlanta	290.8	330.5	272.6
Baltimore	278.6	320.5	277.7
Boston	273.6	315.5	268.5
Buffalo	276.5	336.6	284.6
Miami	293.2	343.5	291.2
Newark	275.7	308.6	258.0
New York	256.5	316.6	276.9
Norfolk	280.8	318.4	268.5
Philadelphia	274.6	325.3	282.9
Pittsburgh	273.5	324.2	272.9
Wash., DC	288.0	326.4	285.0
PAD I avg	278.3	324.2	271.2
Chicago	308.9	359.8	305.5
Cleveland	281.0	327.4	272.0
Des Moines	285.6	326.0	268.0
Detroit	275.7	324.9	275.4
Indianapolis	284.9	329.9	276.8
Kansas City	285.2	321.2	262.5
Louisville	298.8	335.7	278.2
Memphis	288.0	327.8	266.8
Milwaukee	273.4	324.7	285.1
Minn.-St. Paul	279.7	320.1	268.0
Oklahoma City	283.0	318.4	263.3
Omaha	283.5	329.9	273.4
St. Louis	278.9	314.9	268.6
Tulsa	276.8	312.2	264.9
Wichita	271.4	314.8	267.1
PAD II avg	283.7	325.9	267.2
Albuquerque	283.4	319.8	273.6
Birmingham	291.1	329.8	267.8
Dallas-Fort Worth	285.4	323.8	272.3
Houston	284.4	322.8	268.5
Little Rock	287.5	327.7	266.1
New Orleans	287.1	325.5	266.0
San Antonio	279.3	317.7	256.2
PAD III avg	285.4	323.9	261.0
Cheyenne	282.4	314.8	257.3
Denver	294.1	334.5	271.0
Salt Lake City	284.0	326.9	263.0
PAD IV avg.	286.8	325.4	260.6
Los Angeles	294.2	352.7	324.5
Phoenix	273.4	310.6	285.1
Portland	304.4	347.7	302.2
San Diego	306.2	364.7	334.0
San Francisco	322.0	380.5	348.9
Seattle	303.3	355.7	309.1
PAD V avg.	300.5	352.0	317.3
Week's avg.	**285.2**	**328.8**	**278.6**
Mar. avg.	**276.1**	**319.7**	**254.0**
Feb. avg.	**259.5**	**303.1**	**228.0**
2008 to date	**267.7**	**311.3**	—
2007 to date	**196.8**	**240.4**	—

*Includes state and federal motor fuel taxes and state sales tax. Local governments may impose additional taxes.
Source: Oil & Gas Journal.
Data available in OGJ Online Research Center.

REFINED PRODUCT PRICES

	4-4-08 ¢/gal		4-4-08 ¢/gal
Spot market product prices			
		Heating oil	
Motor gasoline		No. 2	
(Conventional-regular)		New York Harbor	305.28
New York Harbor	257.67	Gulf Coast	298.78
Gulf Coast	268.92	Gas oil	
Los Angeles	295.67	ARA	307.62
Amsterdam-Rotterdam-		Singapore	308.19
Antwerp (ARA)	NA		
Singapore	269.19	Residual fuel oil	
Motor gasoline		New York Harbor	180.67
(Reformulated-regular)		Gulf Coast	182.21
New York Harbor	257.67	Los Angeles	192.23
Gulf Coast	288.67	ARA	199.29
Los Angeles	299.67	Singapore	191.02

Source: DOE Weekly Petroleum Status Report.
Data available in OGJ Online Research Center.

BAKER HUGHES RIG COUNT

	4-11-08	4-13-07
Alabama	6	3
Alaska	9	11
Arkansas	43	43
California	36	32
Land	35	31
Offshore	1	1
Colorado	123	107
Florida	0	0
Illinois	0	0
Indiana	2	2
Kansas	12	14
Kentucky	12	9
Louisiana	140	189
N. Land	47	59
S. Inland waters	18	27
S. Land	22	38
Offshore	53	65
Maryland	0	0
Michigan	0	2
Mississippi	11	21
Montana	12	23
Nebraska	0	0
New Mexico	76	76
New York	7	6
North Dakota	55	30
Ohio	12	14
Oklahoma	210	178
Pennsylvania	24	17
South Dakota	3	2
Texas	879	828
Offshore	7	10
Inland waters	1	1
Dist. 1	24	21
Dist. 2	37	33
Dist. 3	53	53
Dist. 4	91	90
Dist. 5	183	171
Dist. 6	122	127
Dist. 7B	31	48
Dist. 7C	71	61
Dist. 8	126	110
Dist. 8A	22	23
Dist. 9	35	30
Dist. 10	76	50
Utah	38	43
West Virginia	23	29
Wyoming	72	70
Others—NV-3; TN-3; VA-4	10	9
Total US	**1,815**	**1,758**
Total Canada	**112**	**97**
Grand total	**1,927**	**1,855**
Oil rigs	355	282
Gas rigs	1,451	1,472
Total offshore	62	76
Total cum. avg. YTD	**1,777**	**1,735**

Rotary rigs from spudding in to total depth. Definitions, see OGJ Sept. 18, 2006, p. 46.

Source: Baker Hughes Inc.
Data available in OGJ Online Research Center.

SMITH RIG COUNT

Proposed depth, ft	4-11-08 Rig count	4-11-08 Percent footage*	4-13-07 Rig count	4-13-07 Percent footage*
0-2,500	71	5.6	62	6.4
2,501-5,000	120	53.3	100	61.0
5,001-7,500	209	16.7	201	23.8
7,501-10,000	429	2.7	421	3.8
10,001-12,500	484	3.9	420	3.8
12,501-15,000	296	—	256	—
15,001-17,500	119	—	112	0.8
17,501-20,000	71	—	72	—
20,001-over	37	—	38	—
Total	**1,836**	**7.2**	**1,682**	**8.6**
INLAND	30		35	
LAND	1,749		1,587	
OFFSHORE	57		60	

*Rigs employed under footage contracts.
Definitions, see OGJ, Sept. 18, 2006, p. 42.

Source: Smith International Inc.
Data available in OGJ Online Research Center.

OGJ PRODUCTION REPORT

	[1]4-11-08	[2]4-13-07
	1,000 b/d	
(Crude oil and lease condensate)		
Alabama	16	20
Alaska	715	746
California	653	666
Colorado	44	53
Florida	5	5
Illinois	26	27
Kansas	95	98
Louisiana	1,355	1,319
Michigan	14	17
Mississippi	52	55
Montana	93	89
New Mexico	164	164
North Dakota	115	116
Oklahoma	172	169
Texas	1,340	1,340
Utah	45	50
Wyoming	144	146
All others	63	71
Total	**5,111**	**5,151**

[1]OGJ estimate. [2]Revised.

Source: Oil & Gas Journal.
Data available in OGJ Online Research Center.

US CRUDE PRICES

	4-11-08 $/bbl*
Alaska-North Slope 32°	88.35
South Louisiana Sweet	112.00
California-Kern River 13°	97.60
Lost Hills 30°	106.00
Southwest Wyoming Sweet	101.64
East Texas Sweet	106.00
West Texas Sour 34°	99.00
West Texas Intermediate	106.50
Oklahoma Sweet	106.50
Texas Upper Gulf Coast	103.00
Michigan Sour	99.50
Kansas Common	105.75
North Dakota Sweet	102.75

*Current major refiner's posted prices except North Slope lags 2 months. 40° gravity crude unless differing gravity is shown.

Source: Oil & Gas Journal.
Data available in OGJ Online Research Center.

WORLD CRUDE PRICES

	4-4-08 $/bbl[1]
United Kingdom-Brent 38°	101.35
Russia-Urals 32°	96.24
Saudi Light 34°	98.81
Dubai Fateh 32°	96.44
Algeria Saharan 44°	104.24
Nigeria-Bonny Light 37°	104.73
Indonesia-Minas 34°	102.47
Venezuela-Tia Juana Light 31°	98.30
Mexico-Isthmus 33°	98.19
OPEC basket	100.45
Total OPEC[2]	98.88
Total non-OPEC[2]	97.79
Total world[2]	98.39
US imports[3]	95.56

[1]Estimated contract prices. [2]Average price (FOB) weighted by estimated export volume. [3]Average price (FOB) weighted by estimated import volume. Source: DOE Weekly Petroleum Status Report.
Data available in OGJ Online Research Center.

US NATURAL GAS STORAGE[1]

	4-4-08	3-28-08	4-4-07	Change, %
		bcf		
Producing region	498	498	638	–21.9
Consuming region east	563	575	705	–20.1
Consuming region west	173	175	242	–28.5
Total US	**1,234**	**1,248**	**1,585**	**–22.1**
	Jan. 08	**Jan. 07**	**Change, %**	
Total US[2]	**2,055**	**2,379**	**–13.6**	

[1]Working gas. [2]At end of period.
Source: Energy Information Administration.
Data available in OGJ Online Research Center.

Statistics

INTERNATIONAL RIG COUNT

Region	Mar. 2008 Land	Mar. 2008 Off.	Mar. 2008 Total	Mar. 07 Total
WESTERN HEMISPHERE				
Argentina	87	—	87	87
Bolivia	3	—	3	4
Brazil	23	26	49	41
Canada	407	2	408	392
Chile	1	—	1	1
Colombia	42	—	42	32
Ecuador	7	—	7	11
Mexico	66	30	96	91
Peru	7	1	8	9
Trinidad	—	6	6	7
United States	1,737	60	1,797	1,749
Venezuela	66	15	81	80
Other	—	—	—	2
Subtotal	**2,446**	**139**	**2,585**	**2,505**
ASIA-PACIFIC				
Australia	13	9	22	17
Brunei	1	2	3	4
China-offshore	—	16	16	18
India	56	25	81	84
Indonesia	38	24	62	49
Japan	3	—	3	1
Malaysia	—	10	10	15
Myanmar	7	1	8	9
New Zealand	3	3	6	3
Papua New Guinea	4	—	4	3
Philippines	1	—	1	—
Taiwan	—	—	—	—
Thailand	2	7	9	13
Vietnam	—	7	7	7
Other	1	2	3	4
Subtotal	**129**	**106**	**235**	**227**
AFRICA				
Algeria	30	—	30	26
Angola	—	4	4	5
Congo	1	1	2	3
Gabon	1	2	3	2
Kenya	—	—	—	—
Libya	14	1	15	13
Nigeria	4	7	11	8
South Africa	—	—	—	—
Tunisia	2	2	4	2
Other	—	1	1	6
Subtotal	**52**	**18**	**70**	**65**
MIDDLE EAST				
Abu Dhabi	9	2	11	12
Dubai	1	—	1	1
Egypt	39	7	46	46
Iran	—	—	—	—
Iraq	—	—	—	—
Jordan	—	—	—	1
Kuwait	14	—	14	12
Oman	53	–	53	46
Pakistan	20	–	20	19
Qatar	2	9	11	14
Saudi Arabia	65	13	78	75
Sudan	—	—	—	—
Syria	21	—	21	19
Yemen	13	—	13	14
Other	1	—	1	1
Subtotal	**238**	**31**	**269**	**260**
EUROPE				
Croatia	—	—	—	1
Denmark	—	2	2	3
France	2	—	2	1
Germany	7	1	8	5
Hungary	3	—	3	2
Italy	5	—	5	3
Netherlands	—	3	3	5
Norway	—	22	22	16
Poland	2	—	2	2
Romania	17	3	20	2
Turkey	5	—	5	5
UK	1	21	22	25
Other	6	—	6	7
Subtotal	**48**	**52**	**100**	**77**
Total	**2,913**	**346**	**3,259**	**3,134**

Definitions, see OGJ Sept. 18, 2006, p. 42.
Source: Baker Hughes Inc.
Data available in OGJ Online Research Center.

OIL IMPORT FREIGHT COSTS*

Source	Discharge	Cargo	Cargo size, 1,000 bbl	Freight (Spot rate) worldscale	$/bbl
Caribbean	New York	Dist.	200	190	1.61
Caribbean	Houston	Resid.	380	190	1.81
Caribbean	Houston	Resid.	500	224	2.13
N. Europe	New York	Dist.	200	302	4.13
N. Europe	Houston	Crude	400	198	3.99
W. Africa	Houston	Crude	910	163	3.62
Persian Gulf	Houston	Crude	1,900	90	3.70
W. Africa	N. Europe	Crude	910	180	2.96
Persian Gulf	N. Europe	Crude	1,900	89	2.68
Persian Gulf	Japan	Crude	1,750	106	2.58

*March 2008 average.
Source: Drewry Shipping Consultants Ltd. Data available in OGJ Online Research Center.

WATERBORNE ENERGY INC. US LNG IMPORTS

Country	Apr. 2008	Mar. 2008	Apr. 2007	Change from a year ago, %
	MMcf			
Algeria	—	—	24,450	—
Egypt	—	—	14,190	—
Equatorial Guinea	—	—	—	—
Nigeria	3,030	—	9,030	–66.4
Norway	—	3,030	—	—
Qatar	—	—	—	—
Trinidad and Tobago	30,320	22,050	50,870	–40.4
Total	**33,350**	**25,080**	**98,540**	**–66.2**

Source: Waterborne Energy Inc.
Data available in OGJ Online Research Center.

PROPANE PRICES

	Feb. 2008	Mar. 2008	Feb. 2007	Mar. 2007
	¢/gal			
Mont Belvieu	142.52	147.47	97.55	103.71
Conway	148.92	146.63	96.77	100.47
Northwest Europe	159.06	165.01	100.83	100.54

Source: EIA Weekly Petroleum Status Report
Data available in OGJ Online Research Center.

MUSE, STANCIL & CO. REFINING MARGINS

	US Gulf Coast	US East Coast	US Mid-west	US West Coast	North-west Europe	South-east Asia
	$/bbl					
Mar. 2008						
Product revenues	122.64	112.25	116.20	120.95	116.27	111.63
Feedstock costs	–107.28	–107.13	–102.63	–98.97	–103.91	–103.78
Gross margin	15.36	5.12	13.57	21.98	12.36	7.85
Fixed costs	–2.08	–2.41	–2.34	–2.73	–2.34	–1.82
Variable costs	–2.58	–1.66	–2.27	–4.07	–3.60	–1.06
Cash operating margin	**10.70**	**1.05**	**8.96**	**15.18**	**6.42**	**4.97**
Feb. 2008	8.82	1.02	6.86	16.60	5.08	1.23
YTD avg.	8.46	0.96	8.07	13.94	4.53	2.95
2007 avg.	12.36	6.36	18.60	20.89	5.75	2.26
2006 avg.	12.39	6.13	14.91	23.69	5.88	1.06
2005 avg.	12.53	6.98	12.31	20.55	5.51	1.52

Source: Muse, Stancil & Co. See OGJ, Jan. 15, 2001, p. 46
Data available in OGJ Online Research Center.

MUSE, STANCIL & CO. GASOLINE MARKETING MARGINS

Feb. 2008	Chicago*	Houston	Los Angeles	New York
	¢/gal			
Retail price	310.60	296.30	317.62	316.83
Taxes	57.52	38.40	60.82	52.12
Wholesale price	241.94	249.46	250.63	250.86
Spot price	224.46	238.74	258.74	234.84
Retail margin	11.16	8.44	6.17	13.85
Wholesale margin	17.48	10.72	–8.11	16.02
Gross marketing margin	**28.64**	**19.16**	**–1.94**	**29.87**
Jan. 2008	34.12	28.02	25.76	38.85
YTD avg.	31.38	23.59	11.91	34.36
2007 avg.	26.96	23.12	19.05	31.10
2006 avg.	19.74	20.34	18.03	27.90
2005 avg.	19.77	16.26	20.39	27.13

*The wholesale price shown for Chicago is the RFG price utilized for the wholesale margin. The Chicago retail margin includes a weighted average of RFG and conventional wholesale purchases.
Source: Muse, Stancil & Co. See OGJ, Oct. 15, 2001, p. 46.
Data available in OGJ Online Research Center.
Note: Margins include ethanol blending in all markets.

MUSE, STANCIL & CO. ETHYLENE MARGINS

	Ethane	Propane	Naphtha
	¢/lb ethylene		
Mar. 2008			
Product revenues	69.41	116.63	140.44
Feedstock costs	–39.92	–84.02	–136.79
Gross margin	29.49	32.61	3.65
Fixed costs	–5.38	–6.36	–7.19
Variable costs	6.42	–7.62	–10.32
Cash operating margin	**17.69**	**18.63**	**–13.86**
Feb. 2008	19.48	19.34	–6.74
YTD avg.	17.16	17.61	–8.96
2007 avg.	14.41	14.14	–7.42
2006 avg.	19.53	22.44	1.34
2005 avg.	14.43	20.68	1.28

Source: Muse, Stancil & Co. See OGJ, Sept. 16, 2002, p. 46.
Data available in OGJ Online Research Center.

MUSE, STANCIL & CO. US GAS PROCESSING MARGINS

Mar. 2008	Gulf Coast	Mid-continent
	$/Mcf	
Gross revenue		
Gas	9.02	7.52
Liquids	1.59	4.36
Gas purchase cost	10.04	10.09
Operating costs	0.07	0.15
Cash operating margin	**0.51**	**1.64**
Feb. 2008	0.54	1.67
YTD avg.	0.59	1.79
2007 avg.	0.44	1.48
2006 avg.	0.26	0.97
2005 avg.	–0.06	0.25
Breakeven producer payment % of liquids	66%	61%

Source: Muse, Stancil & Co. See OGJ, May 21, 2001, p. 54.
Data available in OGJ Online Research Center.

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Study: Biofuels impeding struggle against poverty

The Editor's Perspective

by Bob Tippee, Editor

Burning food for fuel is hurting hungry people.

This will surprise no one except, perhaps, politicians hawking biofuels. Some still think biofuels fight global warning and ensure energy security.

They're not just incorrect but also—in view of how their mistakes affect the impoverished—wrong.

"Poor people are suffering daily from the impact of high food prices, especially in urban areas and in low-income countries," said World Bank Group Pres. Robert B. Zoellick on Apr. 9.

He was commenting on a new World Bank study of the recent spurt in food prices and appealing for an international response. "In some countries," he said, "hard-won gains in overcoming poverty may now be reversed."

The study says global wheat prices increased by 181% during the 36 months leading up to February. Overall global food prices were up 83%.

Increased biofuel production accounts for much of the increase, the study says. As though anticipating responses typical of biofuel fans, the study points out droughts in Australia and poor crops in Europe and Ukraine in 2006-07 were offset by good crops and increased exports elsewhere.

And only about 15% of the increase in food production prices, the study says, can be attributed directly to increased energy and fertilizer costs.

Relief will take a while.

"Food crop prices are expected to remain high in 2008 and 2009 and then begin to decline as supply and demand respond to high prices," the study says. "However, they are likely to remain well above the 2004 levels through 2015 for most food crops."

The World Bank study diplomatically points out that governments have been pushing biofuels out of concern about global warming and energy supply. It doesn't address the extent to which those supposed benefits have been oversold.

Its central message is that the biofuels surge is impeding the struggle against poverty. Last year, an Organization for Economic Cooperation and Development "round table" challenged the environmental and supply extension claims made on behalf of biofuels (OGJ, Sept. 24, 2007, p. 17). It predicted the food-price jumps documented by the World Bank study.

When will the biofuels nonsense stop?

(Online Apr. 11, 2008; author's e-mail: bobt@ogjonline.com)

Market Journal

by Sam Fletcher, Senior Writer

Energy prices climb

The front-month contract for benchmark US crudes jumped past $112/bbl Apr. 9 following a report that inventories of crude, gasoline, and distillate fuel fell to unexpectedly low levels in the week ended Apr. 4.

The May contract for US sweet, light crudes hit an intraday high of $112.21/bbl before closing at a record $110.87/bbl on the New York Mercantile Exchange. Heating oil and the May IPE contract for North Sea Brent crude also hit new highs in intraday trade as did the April gas oil contract in London.

Prices slipped in the Apr. 10 session but remained near record highs, with markets still concerned about tight supplies and the weak US dollar. Crude prices were essentially flat Apr. 11 but managed a gain for the week as the International Energy Agency in Paris again reduced its estimate of global crude demand for 2008.

The May contract for benchmark US light, sweet crudes increased 3¢ to $110.14/bbl Apr. 11 on the New York Mercantile Exchange. West Texas Intermediate gained $3.91/bbl during the calendar week, set a new record high, but fell 7¢ short of registering the highest weekly close, said Olivier Jakob at Petromatrix, Zug, Switzerland. "Brent gains were at par at [an increase of] $3.85/bbl. Heating oil made much stronger gains, [up] $8.41/bbl while reformulated blend stock for oxygenate blending (RBOB) was adding only $2.12/bbl. Natural gas was up 6.2%," he said.

Jakob said: "WTI continues to be tightly correlated to the movements of the dollar index. However, while in the previous week WTI had spent the week slightly below the correlation, this last week it was slightly above. The main reason why the correlation is so strong is that it has become a self-fulfilling trade with very few volunteers to trade against it until it is proven broken. Gold, which had also been strongly correlated to the dollar, has not followed the correlation as strongly as oil, and the gold to crude ratio continues to come off. For the oil to dollar correlation to be broken would require a set of fundamental numbers bearish enough to be a no-brainer."

IEA's demand estimate

In its Apr. 11 report, IEA reduced its estimate of global crude demand for 2008 by 310,000 b/d to 87.2 million b/d on the downgrading of global gross domestic product prospects by the United Nation's International Monetary Fund, coupled with "a change in former Soviet Union methodology and baseline data revisions," officials said.

On the other hand, IEA increased its estimate of 2007 demand, up 140,000 b/d to 86 million b/d. "As a result of these divergent shifts, demand growth in 2008 is now expected at almost 1.3 million b/d, or 1.5% over 2007," the agency reported.

Its estimate of global oil supply fell by 100,000 b/d in March to 87.3 million b/d, due to reduced supplies from the Organization of Petroleum Exporting Countries, the North Sea, and non-OPEC Africa. "Non-OPEC supply growth in 2008 is trimmed to 815,000 b/d on a broad swathe of adjustments in the Americas, Africa, and Europe," IEA said.

It said, "OPEC crude supply fell by 265,000 b/d in March to 32.1 million b/d, on field maintenance in the UAE, Nigeria, and Venezuela. Pipeline and power outages highlighted ongoing risks to production in Iraq and Nigeria amid effective spare capacity of just 2.3 million b/d. Weaker economic growth cuts the 2008 call on OPEC by 300,000 b/d to 31.6 million b/d."

Global refinery throughput weakened in March, as poor margins curbed crude runs in all regions of the Organization for Economic Cooperation and Development. IEA's estimated first quarter 2008 global throughput remained unchanged at 74 million b/d. However, it reduced second quarter estimates by 200,000 b/d to 73.7 million b/d, in line with weaker demand.

IEA's reduction of its world demand outlook was "actually the largest revisions made since [the Sept. 11, 2001, terrorist attacks on the US], and the total lack of immediate market response is showing to the IEA what OPEC has been saying all along, and that is that the oil futures market is currently not trading the oil fundamentals," said Jakob. "At the time of the IEA release, the dollar was trending lower, and there are just not any volunteers ready to trade a bearish IEA report against the dollar." Analysts in the Houston office of Raymond James & Associates Inc. said, "We continue to believe that both the IEA's demand and non-OPEC supply numbers are too high."

The US dollar fell against most major currencies as finance ministers of the Group of Seven leading nations met in Washington, D.C., Apr. 11-13.

(Online Apr. 14, 2008; author's e-mail: samf@ogjonline.com)