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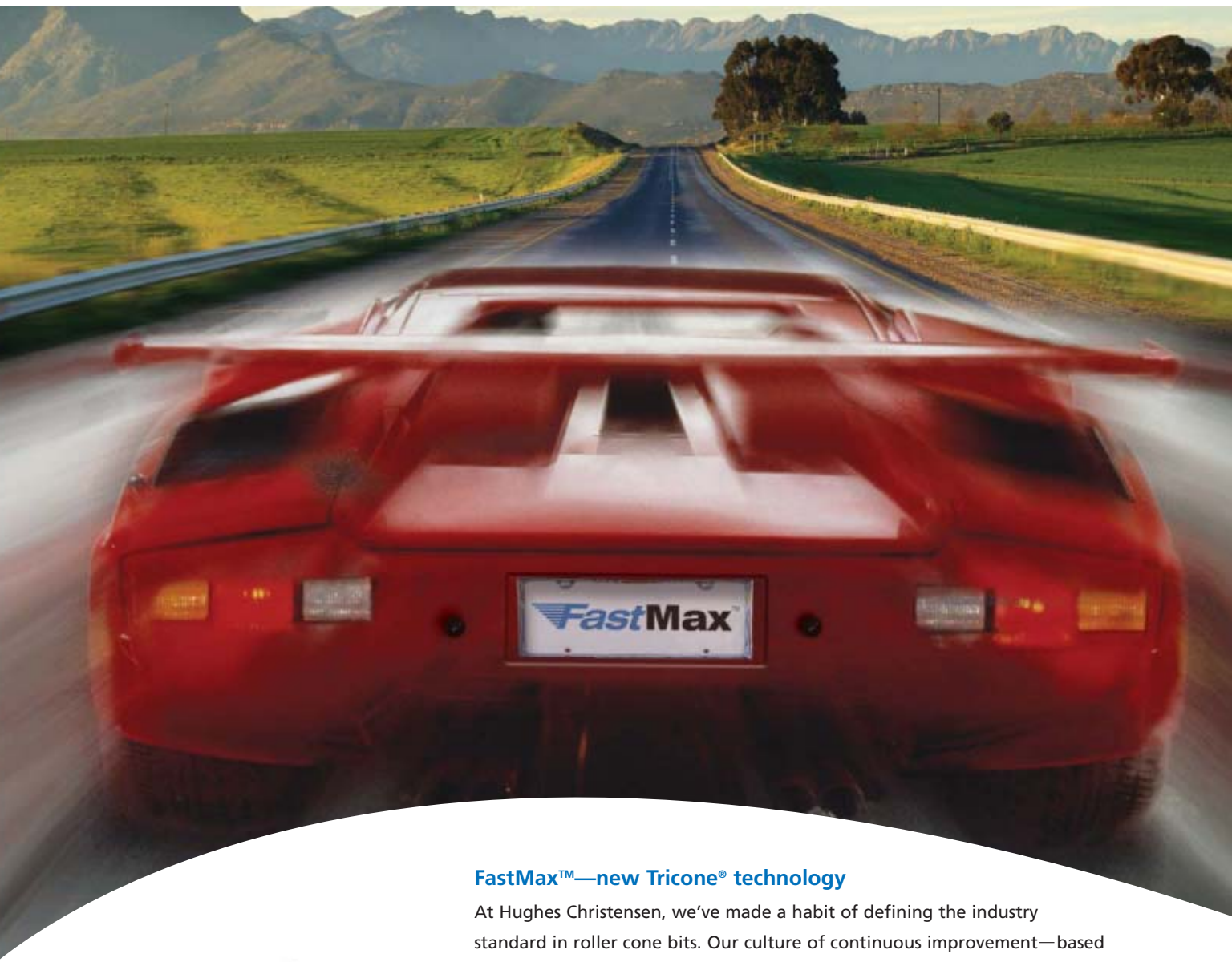


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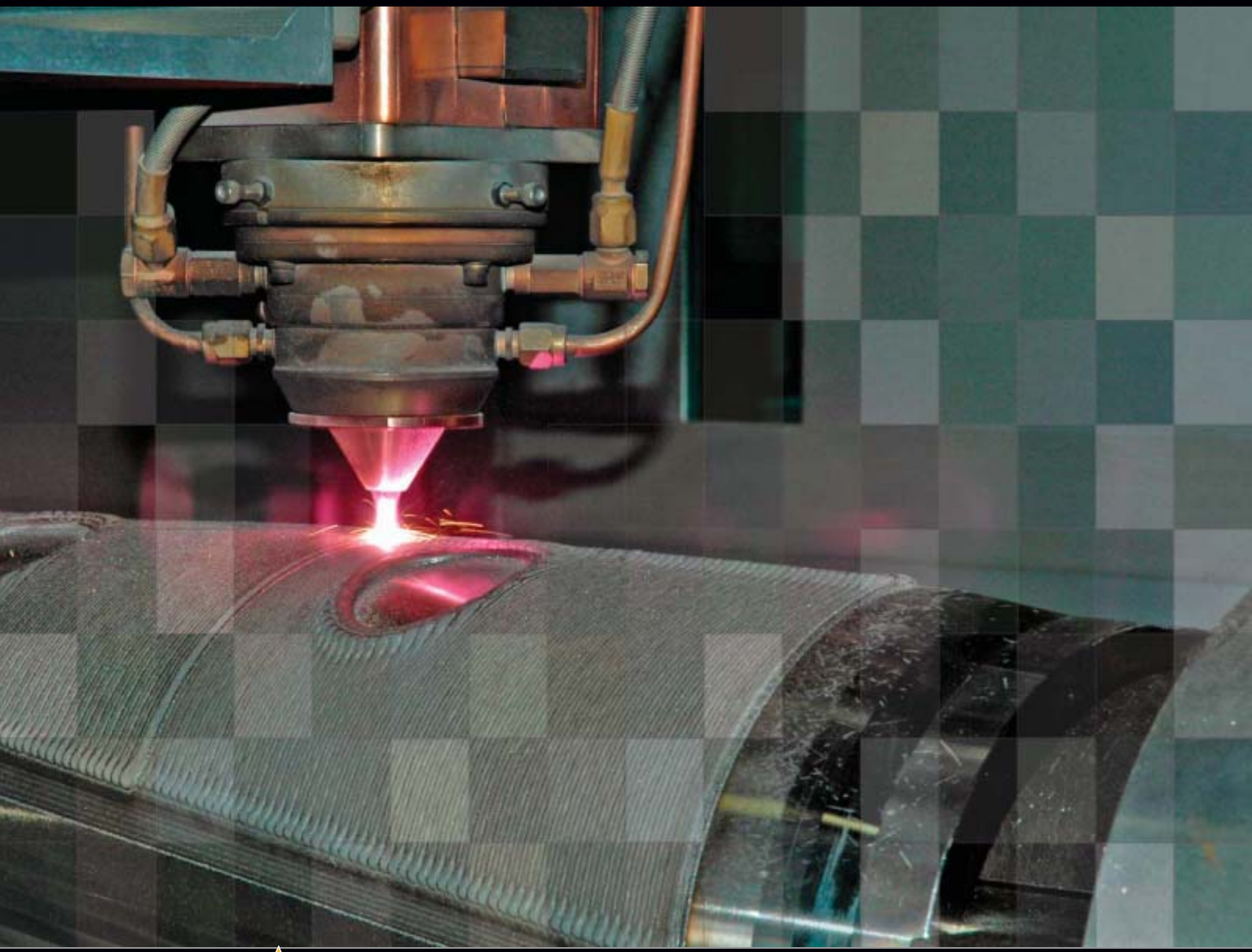



## Modern Materials

***Part 2—Refining dynamics counter public misperceptions***
***Middle East field sizes and reserves growth draw focus***
***Coating heat-transfer equipment enhances efficiency***

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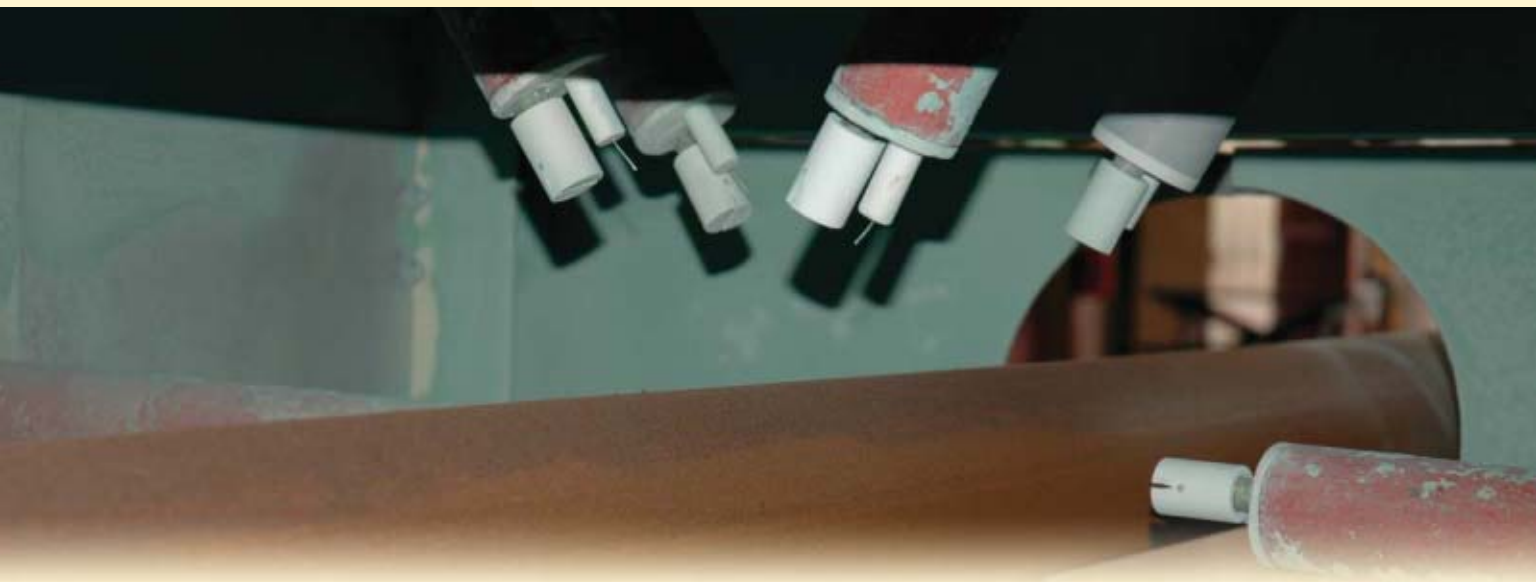
## MODERN MATERIALS





## REGULAR FEATURES



## COVER

A fiber-delivered diode laser clads drilling tools with Lasercarb powder through a coaxial nozzle at a Technogenia plant in Saint-Jorioz, France. A computer control system allows precise cladding on complex surfaces to enhance wear and corrosion resistance of downhole equipment. An article on laser cladding begins OGJ's Modern Materials special report on p. 43. The next article, beginning on p. 52, discusses advanced fiber-reinforced polymer composites that offer new options for completing deep wells with high temperatures and pressures and corrosive fluids. The final article discusses commercially available filler metals for 36Ni alloy cryogenic pipeline construction and begins on p. 68. Nozzles in the photo above continuously coat coiled tubing at Stewart & Stevenson's Houston plant (photo by Nina M. Rach). Cover photo by Robert Gravet, Technogenia.

# There are 193 countries in the world. None of them are energy independent.

So who's holding whom over a barrel?


The fact is, the vast majority of countries rely on the few energy-producing nations that won the geological lottery, blessing them with abundant hydrocarbons. And yet, even regions with plenty of raw resources import some form of energy. Saudi Arabia, for example, the world's largest oil exporter, imports refined petroleum products like gasoline.

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## General Interest



## Exploration & Development



## Drilling & Production



## Processing



## Transportation



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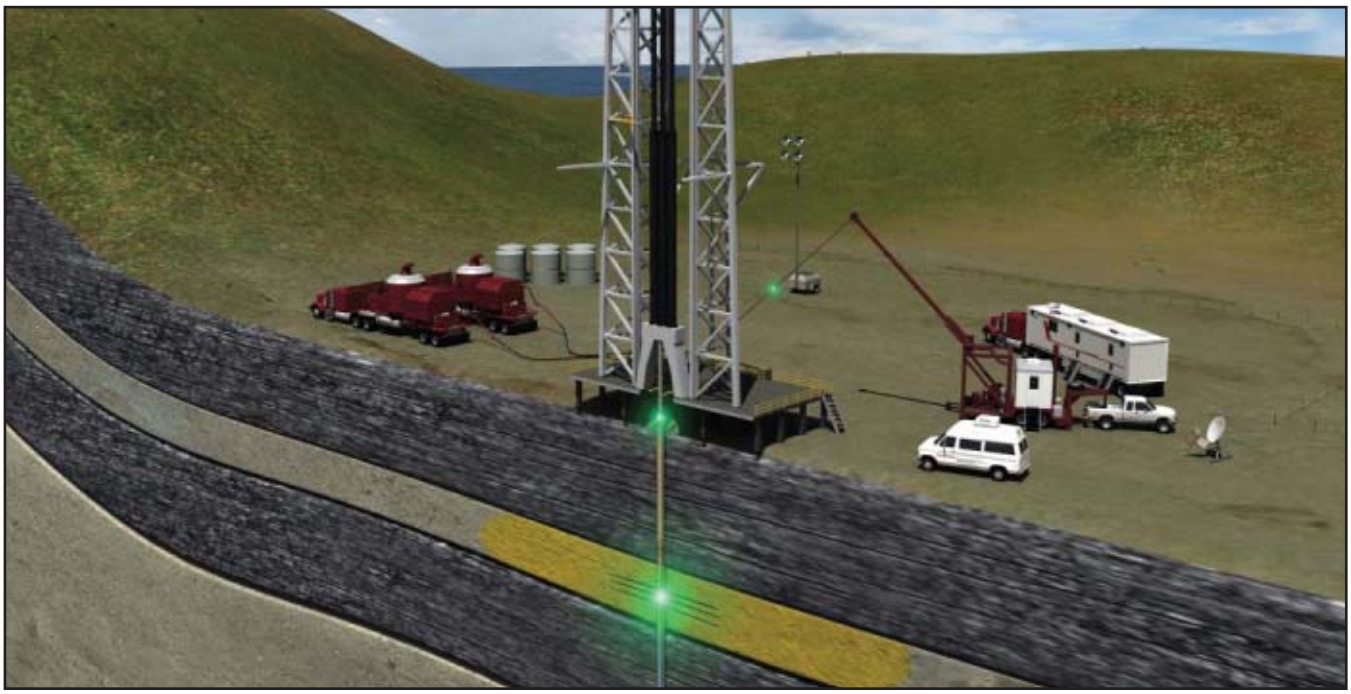

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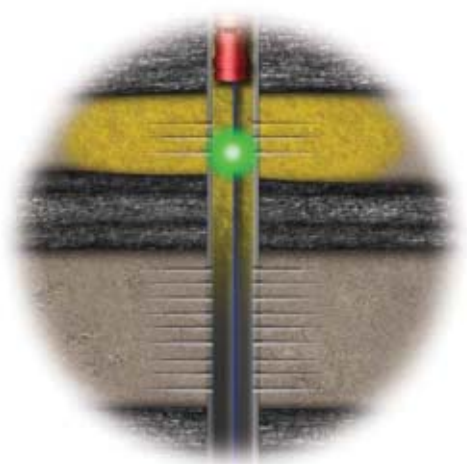

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Sept. 10, 2007

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## General Interest — Quick Takes

### Kazakhstan may extend Kashagan suspension order

The Kazakh government has threatened to extend its suspension order of work at Kashagan oil field if the Eni SPA-led consortium does not address the operational issues hindering the project.

Kazakhstan stopped the group from continuing work at Kashagan on Aug. 27 claiming breach of environmental standards, cost overruns, and delays (OGJ Online, Aug. 28, 2007).

Analysts have interpreted the action as a move to gain higher revenues from the project.

Production, planned to start in 2005, has been postponed to 2010. Eni has suggested that operational costs could rise to $136 billion from $57 billion. The group plans to develop the field by drilling about 280 wells and building offshore platforms and artificial islands.

According to media reports, the Kazakh authorities are now pressing the consortium to propose "an adequate compensation" and reforms in the structure of the deal by Sept. 5 to drive its future implementation.

Kazakhstan has said that it is prepared to change the operator if need be, but this does not necessarily mean appointing state oil company KazMunaiGaz as the replacement. However, even if KazMunaiGaz took control, the issue is whether it has the technical experience or financial resources to manage the field efficiently.

Kashagan is an important project for future non-OPEC oil supplies to the West, which is trying to persuade Kazakhstan to direct Caspian oil away from Russia, China, or Iran.

### NPRA: Keep primary ozone standard

The National Petrochemical & Refiners Association supports keeping the primary ozone standard in US clean-air regulations, NPRA environment director David Friedman testified Aug. 30 before a US Environmental Protection Agency hearing in Philadelphia.

EPA is considering lowering the National Ambient Air Quality Standard (NAAQS) for ground-level ozone to 0.07 ppm from 0.08 ppm, said Alison Davis, EPA spokeswoman for air and radiation.

Some environmentalists and medical experts support a stricter standard of 0.06 ppm. But Friedman said changing the NAAQS is unnecessary.

"Many states have not yet completed plans to attain the current standard, so EPA should focus on helping communities meet the current standard," Friedman said. NPRA members have worked to improve air quality, and they acknowledge the efforts undertaken by the EPA, state governments, and local communities, Friedman said.

"The science behind lowering the standard is uncertain and variable, and therefore this is not the right time to change it," he said. "There are many questions regarding the state of the science and, in particular, whether or not there have been any significant developments over the past 10 years that would warrant further revisions of the standard."

### BLM seeks comments for northeastern NPR-A

The Bureau of Land Management (BLM) is soliciting public comment on its draft supplemental environmental impact statement to address proposed oil and gas activities in the northeastern portion of the National Petroleum Reserve-Alaska (NPR-A) area.

The public comment period on the draft document is scheduled for Aug. 24-Oct. 23, a BLM release said. The northeastern NPR-A area covers 4.6 million acres.

The public comment is part of a mandatory process as outlined in the National Environmental Protection Act (NEPA). BLM anticipates a possible NPR-A lease sale in the second half of 2008, but no definite date will be set pending completion of the NEPA process, a BLM spokeswoman in Anchorage told OGJ on Aug. 29.

Tom Lonnie, BLM-Alaska state director, said the supplemental plan will allow the agency to consider the lands appropriate for leasing "and the restrictions we should place on exploration and development that will result in petroleum production while protecting the area's important resources."

BLM began developing the supplement in December 2006 in response to a Sept. 25, 2006, ruling from the US District Court for the District of Alaska that stated the 2005 northeastern NPR-A amended integrated activity plan-EIS failed to adequately address cumulative impacts.

### Nicaragua taxes Esso, embargoes assets

Nicaragua's vice-president has ordered Esso Standard Oil to pay $3 million in taxes on allegedly undeclared oil imports, while a judge has embargoed the company's assets.

Vice-President Jaime Morales Carazo said transnational companies are not exempt from paying such taxes, a claim Esso denies. Esso spokesman Alfredo Fernandez said the company owes no taxes because the importation of oil into Nicaragua is tax-exempt by national law.

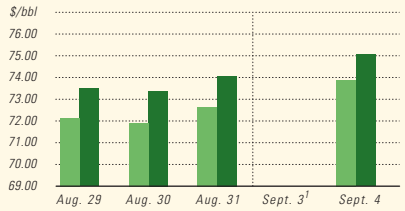
The Superior Council of Private Business sent a letter to Nicaraguan President Daniel Ortega saying that the tax claim and embargo "could damage the image of his government and the nation, which needs so much investment."

The US Embassy in Nicaragua said the move has the potential to seriously damage economic relations between the US and Nicaragua.

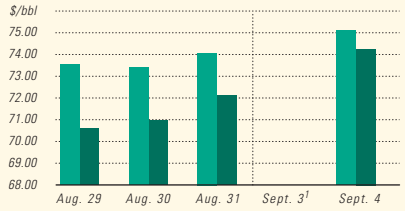
Ortega has been negotiating with Venezuela President Hugo Chavez to import and refine Venezuelan crude oil. Last month, Chavez and Ortega launched construction of a 150,000 b/d refinery in Piedras Blancas, near Nicaragua's Pacific coast (OGJ Online, July 23, 2007). ✦

# Industry Scoreboard

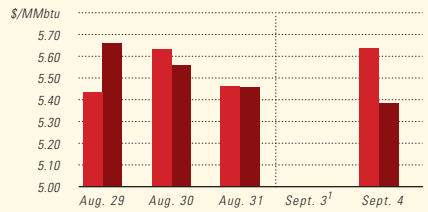
## IPE BRENT / NYMEX LIGHT SWEET CRUDE



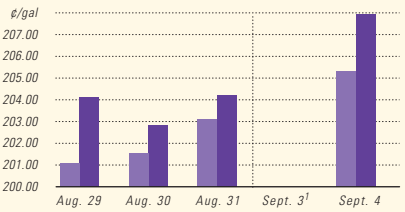

## WTI CUSHING / BRENT SPOT



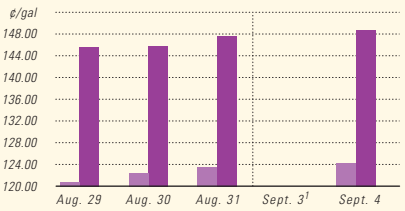

## NYMEX NATURAL GAS / SPOT GAS - HENRY HUB



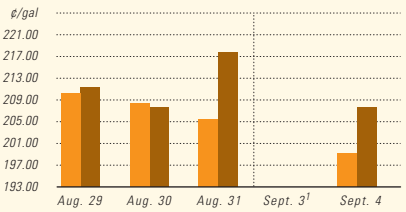

## IPE GAS OIL / NYMEX HEATING OIL




## PROPANE - MT. BELVIEU / BUTANE - MT. BELVIEU




## NYMEX GASOLINE (RBOB)[2] / NY SPOT GASOLINE[3]




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

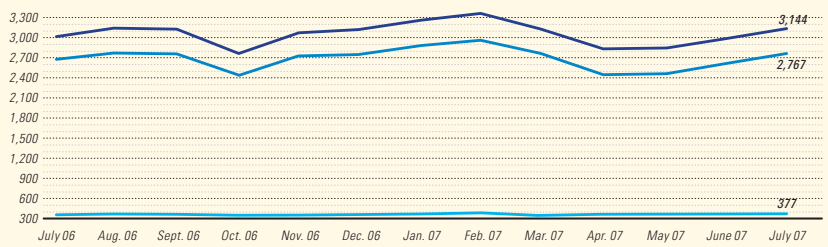
## US INDUSTRY SCOREBOARD — 9/10

| Latest week 8/24 | 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 | 9,643 | 9,585 | 0.6 | 9,319 | 9,211 | 1.2 |
| Distillate | 4,189 | 4,160 | 0.7 | 4,233 | 4,149 | 2.0 |
| Jet fuel | 1,603 | 1,632 | –1.8 | 1,622 | 1,618 | 0.2 |
| Residual | 743 | 740 | 0.4 | 761 | 719 | 5.8 |
| Other products | 5,012 | 5,073 | –1.0 | 4,865 | 4,859 | 0.1 |
| TOTAL DEMAND | 21,199 | 21,190 | — | 20,800 | 20,546 | 1.2 |
| *Supply, 1,000 b/d* | | | | | | |
| Crude production | 5,154 | 5,158 | –0.1 | 5,183 | 5,101 | 1.6 |
| NGL production[2] | 2,463 | 2,245 | 9.7 | 2,380 | 2,186 | 8.9 |
| Crude imports | 10,127 | 10,469 | –3.3 | 10,126 | 10,089 | 0.4 |
| Product imports | 3,469 | 4,005 | –13.4 | 3,568 | 3,623 | –1.5 |
| Other supply[3] | 985 | 1,254 | –21.5 | 932 | 1,137 | –18.0 |
| TOTAL SUPPLY | 22,198 | 23,131 | –4.0 | 22,189 | 22,136 | 0.2 |
| *Refining, 1,000 b/d* | | | | | | |
| Crude runs to stills | 15,693 | 16,227 | –3.3 | 15,249 | 15,221 | 0.2 |
| Input to crude stills | 15,919 | 16,195 | –1.7 | 15,504 | 15,577 | –0.5 |
| % utilization | 91.2 | 93.1 | — | 88.9 | 89.6 | — |

| Latest week 8/24 | Latest week | Previous week[1] | Change | Same week year ago[1] | Change | Change, % |
|---|---|---|---|---|---|---|
| *Stocks, 1,000 bbl* | | | | | | |
| Crude oil | 333,632 | 337,118 | –3,486 | 330,359 | 3,273 | 1.0 |
| Motor gasoline | 192,564 | 196,231 | –3,667 | 205,795 | –13,231 | –6.4 |
| Distillate | 129,914 | 129,025 | 889 | 135,481 | –5,567 | –4.1 |
| Jet fuel-kerosine | 42,153 | 41,918 | 235 | 41,451 | 702 | 1.7 |
| Residual | 38,599 | 36,476 | 2,123 | 41,533 | –2,934 | –7.1 |
| *Stock cover (days)[4]* | | | Change, % | | Change, % | |
| Crude | 21.3 | 21.2 | 0.5 | 21.2 | 0.5 | |
| Motor gasoline | 20.0 | 20.4 | –2.0 | 21.4 | –6.5 | |
| Distillate | 31.0 | 31.0 | — | 33.6 | –7.7 | |
| Propane | 52.7 | 54.7 | –3.7 | 66.3 | –20.5 | |
| *Futures prices[5]* **8/31** | | | Change | | Change | Change, % |
| Light sweet crude, $/bbl | 72.87 | 69.74 | 3.13 | 72.34 | 0.53 | 0.7 |
| Natural gas, $/MMbtu | 5.51 | 5.72 | –0.21 | 6.95 | –1.44 | –20.7 |

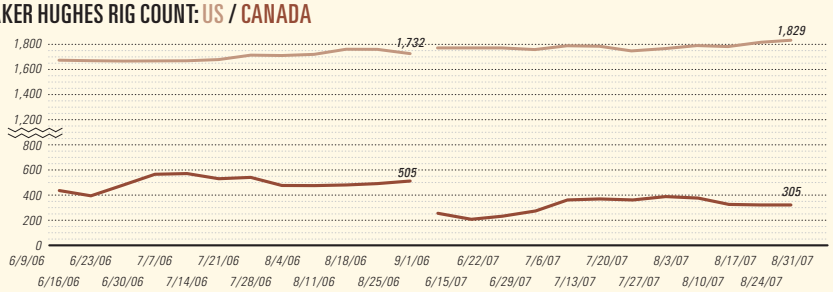
[1]Based on revised figures. [2]Includes adjustments for fuel ethanol and motor gasoline blending components. [3]Includes other hydrocarbons and alcohol, refinery processing gain, and unaccounted for crude oil. [4]Stocks divided by average daily product supplied for the prior 4 weeks. [5]Weekly average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

# Exploration & Development — *Quick Takes*

## ConocoPhillips makes gas find with Harrison well

Operator ConocoPhillips has discovered a 16-m gas column in the lower Ketch formation of its Harrison exploration well (44/19b-6) in the UK southern North Sea.

The well reached a TD of 4,289 m and will be flow tested with results expected later this month. Harrison is 20 km to the northeast of the Murdoch platform. All of the drilling was completed ahead of schedule and under budget.

Aidan Heavey, chief executive of Tullow Oil PLC, a partner in the well, said early assessment of the well's data show that it is in line with the company's predrill expectations.

## Petrobras to boost Amazon gas exploration

Brazil's state-owned Petroleo Brasileiro (Petrobras) plans to step up exploration for natural gas in the Amazon rainforest, according to a senior company official.

Petrobras plans to launch gas production in 2008 from its Urucu field in northern Amazonas state, where it produces 50,000 b/d of oil, said director of exploration and production Guilherme Estrella on Sept. 3.

Estrella said Urucu field will help meet gas demand growth by 2012 and that Petrobras has a 20-year agreement to supply 5.5 million cu m/day of gas to Amazonas state.

Petrobras plans to drill 23 wells in the Solimoes basin by 2012, he said. Major projects will include Jurua, Jaraqui, and Sao Mateus fields.

Meanwhile, Estrella forecast lower production for Petrobras than earlier predicted. Petrobras's average oil output will stand at about 1.85 million b/d in 2007, down from the earlier target of 1.919 million b/d, Estrella said.

The reduced output resulted from operational problems with platforms P-34, P-50, P-43, and P-48. According to Estrella, however, most problems have been resolved.

## Final notice issued for central gulf sale

The US Minerals Management Service issued a final notice for central Gulf of Mexico Outer Continental Shelf Lease Sale 205, which covers 28.5 million acres of submerged land in federal waters off Louisiana, Mississippi, and Alabama. The sale will be held Oct. 3 in New Orleans.

Sale 205 offers about 5,000 blocks 3-224 miles offshore in 12-11,200 ft of water in what is the newly configured central Gulf of Mexico OCS Planning Area.

Sale 205 is the first central gulf lease sale in the agency's 2007-12 OCS leasing program.

MMS estimates the sale could result in the production of 0.776-1.292 billion bbl of oil and 3.236-5.229 tcf of natural gas. ✦

# Drilling & Production — *Quick Takes*

## Alabama strat trap oil field still growing

A southern Alabama oil field with a unique trapping mechanism is still under development after having become the state's largest producing field in 2005.

Midroc Operating Co., private Dallas independent, has drilled more than 40 wells into the Little Cedar Creek field Jurassic Smackover limestone reservoir since becoming operator of the field in May 2000. Hunt Oil Co., Dallas, discovered the field in Conecuh County in 1994.

The field is near the updip limit of the Smackover formation, and the trapping mechanism is interpreted as stratigraphic, the Alabama Oil & Gas Board reports. There is no faulting or structural closure based on current well control, and the Smackover displays monoclinal dip to the southwest at a rate of 200 ft/mile.

"This trapping mechanism is unique among Jurassic reservoirs throughout the entire Gulf Coast region," the board said.

The discovery well, Cedar Creek Land & Timber Co. 30-1, in 30-4n-12e, 10 miles southeast of Evergreen, Ala., went to a TD of 12,100 ft. It flowed 108 b/d of oil and 49 Mcfd of gas on a $^{12}/_{64}$-in. choke with 248 psi flowing tubing pressure from the Smackover.

Subsequent drilling by Midroc on 160-acre spacing has expanded the field limits to include more than 10,000 acres in 4n-12e and 4n-13e. Development continues mainly to the northeast.

Little Cedar Creek field produced 1.17 million bbl of oil in 2005 and 1.64 million bbl in 2006, helping reverse the state's declining oil production trend, the board noted.

The Smackover pool "consists of two main porosity zones separated by a dense nonproductive zone." The pool is officially defined as Smackover strata between 11,490 ft and 11,580 ft in the Pugh 22-2 well in 22-4n-12e.

## Amerisur moves rig to Colombia's Putumayo basin

Colombia's state-owned Ecopetrol SA has authorized mobilization of the Pride-17 drilling rig to the Platanillo block in Colombia's Putumayo basin, reported partner Amerisur Resources PLC.

Platanillo is an "advanced project with near-term production potential," said Amerisur chief executive officer John Wardle. The firm said rig mobilization will take about 3 weeks and that it expects the well to spud in early to mid-September, followed by testing and results in October.

The rig will drill a second well, Platanillo-2, immediately following the drilling of Platanillo-1, Amerisur said. The location of Platanillo-2 will depend on results obtained in Platanillo-1. Subject to the possibility of additional civil works, it is expected that Platanillo-2 will be spudded in October.

The firm said negotiations are continuing regarding the acquisition of an increased working interest in the Platanillo contract. The current stakeholders are operator Ecopetrol 40%, Repsol YPF SA 35%, and Amerisur 25%.

## Delays raise Long Lake oil sands project costs

Nexen Inc. said labor problems have delayed construction and

start-up at the Long Lake oil sands development 200 miles north of Edmonton, Alta. and increased the project's capital cost by 10-15% above the previous forecast of $5.3 billion.

Nexen said the sulfur recovery unit is slated for completion in first quarter 2008 because of lower than expected labor productivity and difficulties securing sufficient labor, particularly pipefitters, to work on the sulfur recovery unit, said Charlie Fischer, Nexen's president and chief executive. The pace of commissioning activities also is slower than expected, he added.

However he said the work is almost complete, and the company expects to have sufficient laborers for all remaining activities.

Progress on other units of the upgrader also has been slower than expected. Completion of the hydrocracker, the OrCrude unit, and all main plant utilities are expected in the third quarter of this year and the gasifier and air separation units, in the fourth quarter.

Commissioning has commenced on the utility steam boilers, with start-up expected during the third quarter.

Full start-up of the upgrader is now expected to begin in the first and second quarters of 2008.

Commissioning and start up of the steam-assisted gravity drainage (SAGD) plant and wells is under way. The company currently is injecting steam into 4 of the 10 well pads and expects to be steaming all well pads by the end of September.

"SAGD performance at Long Lake is as expected or slightly better, and we expect bitumen production to ramp up to full rates over the next 12-24 months" Fischer said.

Production of synthetic crude oil is expected late in second-quarter 2008. The company expects the upgrader to reach full production capacity 12-18 months after start-up.

"We expect to produce synthetic crude oil at Long Lake for several decades and benefit from a significant operating cost advantage," Fischer said. Despite the increase in capital costs, "project returns from Long Lake at current commodity prices are higher than [was] expected at the time of sanctioning." ✦

## Processing — *Quick Takes*

### NPRA: US refining capacity climbed 0.6% in 2006

US refining capacity grew 0.6% during 2006 to 17.4 million b/cd of distillation capacity and 18.4 million b/sd as of Jan. 1, reported the National Petrochemical & Refiners Association Aug. 22 in its annual refining and storage capacity report. The figures exclude capacity in Puerto Rico and the US Virgin Islands.

The trend of adding capacity to existing refineries has continued, said NPRA Executive Vice-Pres. Charles T. Drevna. "While it's true that a brand new refinery hasn't been built since 1976, we've actually, on the aggregate, built the equivalent of one new world-class refinery each year for the past 14 years," he said.

Capacity at 149 operable US refineries at the beginning of this year was 3.9% higher than 5 years earlier and 12.9% higher than at the beginning of 1997, according to NPRA, which used figures compiled by the US Energy Information Administration in its 2007 Petroleum Supply Annual.

However Drevna said expanding domestic capacity has become more challenging because of more-stringent regulations, and the permitting process remains complex and uncertain.

Policymakers also send conflicting signals when they call for more capacity on one hand and 20% cuts in gasoline consumption over 10 years on the other, he observed.

"Refiners make their reinvestments today based on where they see demand headed. If policymakers take actions that significantly decrease consumption, domestic refiners will naturally consider the wisdom of investing in new capacity or facilities only to have those investments stranded in a decade or less," Drevna said.

### Sinopec, CNPC plan 30 refineries in China

China Petrochemical Corp. (Sinopec) and China National Petroleum Corp. (CNPC) are expanding their refining facilities to ease the country's tight oil supply, according to media reports.

China's eobserver.com said Sinopec is scheduled to add and enlarge some 20 refineries with 10 million ton/year production capacity in the next 2-3 years, while CNPC plans to set up 10 refineries, each also having a production capacity of 10 million tons/year.

The financial daily said with completion of the 30 plants, China will have to import more oil because the country's current output of 200 million tons of crude has reached its peak. Now, it said, 50% of China's domestic crude oil consumption relies on imports.

Eobserver.com said Sinopec Group's planned refineries will be built in South and East China, especially in the relatively developed southern areas, where "the strong economic engines are in urgent need of more energy."

It said CNPC will mainly set up its new plants in West China and Northeast China, with plans calling for facilities in Daqing, Fushun, Jinzhou, Huludao, Dalian, Lanzhou, and Xinjiang.

### Brazil starts work on Abreu e Lima refinery

Brazilian President Luiz Inacio Lula da Silva on Sept. 4 officially launched construction on the $4.05 billion Abreu e Lima refinery outside Recife, the largest city in northeastern Brazil and the capital of Pernambuco state.

Noticeably absent from the proceedings were any representatives of Venezuela's state-run Petroleos de Venezuela SA (PDVSA), formerly identified as a 40% partner in the refinery project, with Brazil state-owned Petroleo Brasileiro SA (Petrobras) holding the remaining 60%.

Under a memorandum of understanding between the two state oil companies, the new refinery is expected to process oil from Venezuela's Orinoco Belt and from Marlim field in the Campos basin off Brazil, with each country supplying 50% of the crude oil.

The agreement, however, appears to have hit an impasse over the terms of Petrobras's proposed participation in a project to develop Venezuela's Carabobo field, which was to provide Caracas' share of the oil to be processed at the refinery.

With negotiations over the field continuing, Petrobras said that by second half 2010 the refinery will begin to refine about

200,000 b/d of heavy oil to annually produce 814,000 cu m of petrochemical naphtha, 322,000 tons of LPG, 8.8 million tons of diesel fuel, and 1.4 million tons of oil coke. The products will be marketed locally and in northern-northeastern Brazil.

Petrobras said the refinery's main production focus is on diesel fuel, particularly aimed at supplying the increased demand for derivatives in the northeastern region, which currently is fuel-deficient. The unit will be the first in Brazil to process 100% heavy oil.

In addition, the Abreu e Lima refinery will be capable of producing low-sulfur content derivatives and will be able to comply even with the strict European standards, which specify maximum emission limits of 10 ppm of sulfur. ✦

## Transportation — *Quick Takes*

### Fluxys doubling Zeebrugge LNG terminal capacity

Fluxys LNG has received an €85 million loan from the European Investment Bank toward its program to double the capacity of the Zeebrugge LNG regasification terminal to 6.6 million tonnes/year. The increased capacity is fully booked on a long-term basis, the company said.

Fluxys is adding extra regasification infrastructure and a fourth LNG storage tank under a €165 million investment plan. "Construction works for the capacity increase are nearing completion," Fluxys said. Commissioning is expected to start at yearend.

The loan means that parent company Fluxys can optimize its resources for other infrastructure projects in gas transport and storage.

EIB said it granted the loan because it considers the expansion a priority for Europe in securing competitive and sustainable energy supplies.

"The investment will contribute to increase, secure, and diversify gas supplies to the EU, as imported gas from Zeebrugge can easily be moved to the UK, the Netherlands, Germany, Luxemburg, and France. Environmental benefits will be felt from the completion of this project as well, since it will allow the use of larger volumes of natural gas to replace less environmentally sound fuels," Fluxys said.

Fluxys LNG, with a 93.20% stake, is owner and operator of the Zeebrugge terminal.

### Lukoil completes section of Khauzak pipeline

Lukoil Uzbekistan, a subsidiary of Lukoil Overseas, has completed a 45-km section of 711-mm (28-in.) gas pipeline on the Khauzak block in southwestern Uzbekistan. The line will enable sour gas to be delivered to a tie-in point on the Dengizkul-Mubarek main pipeline.

The line is part of the Kandym-Khauzak-Shady-Kungrad project, which involves the drilling of more than 180 development wells and construction of more than 1,500 km of pipeline and two compressor stations (OGJ Online, July 10, 2007).

The project also involves construction of an 8 billion cu m/year gas processing plant in the Kandym area.

The main gas pipeline for Khauzak gas field will be commissioned at yearend, Lukoil said.

### Work starts on Turkmenistan-China gas line

Construction has started on a 7,000-km pipeline that will deliver 30 billion cu m/year of gas from Turkmenistan to China starting in 2009.

Turkmen President Gurbanguly Berdimuhamedov attended a ceremony at which he made a symbolic weld on the pipeline, which will cross Uzbekistan and Kazakhstan.

About 188 km of the pipeline will be laid in Turkmenistan, 530 km in Uzbekistan, 1,300 km in Kazakhstan, and over 4,500 km in China.

China plans to import 30 billion cu m/year of Turkmen gas for 30 years through the pipeline but has not given the value of the deal.

China National Petroleum Corp. has received exploration rights for Bagtiyarlik territory.

"Turkmenistan is granting a foreign country the right to produce gas on the mainland for the first time," Berdimuhamedov said.

The president, who came to power last December following the death of his predecessor, has welcomed foreign investment in his country's oil and gas industry (OGJ Online, June 15, 2007).

### DNV proposes study for Arctic pipeline standards

Det Norske Veritas is proposing a joint industry project (JIP) to evaluate design methods and recommendations for installation, operation, and maintenance of offshore pipelines in Arctic regions. It also would establish a common practice for addressing the challenges of such operations, which includes ice interaction with surface and subsea offshore installations.

The final results of the JIP will be published as the Recommended Practice (RP) for 'Arctic Offshore Pipelines,' DNV said.

The project could begin by yearend 2007 or early 2008 and is expected to take 18-24 months to complete.

The estimated costs are 400 kroner ($68,000)/operator and 200 kroner ($34,000)/contractor.

"Operators, regulators, designers, pipeline contractors, specialists, research institutions, and universities are invited to participate in the JIP, both through funding and through work-in-kind contributions," said Catherine Jahre-Nilsen, DNV's project manager.

The areas tentatively identified for the RP to address include design philosophy and design principles; design concepts; routing; line pipe; ice interaction loads (simple and advanced approaches; pipeline protection; fabrication and installation; and operation, inspection, and repair.

The RP will be an official code for use by pipeline operators and designers, and will present a common and documented approach that supplements the requirements of DNV-OS-F101 (offshore standards for submarine pipeline systems) and other internationally recognized pipeline codes.

It will be subsequently updated and maintained to reflect ongoing research and development, future JIPs, and project experience. ✦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# Letters

## Damon and Bourne

Thanks so much for your Editor's Perspective on actor Matt Damon's appearance in a video calling for government energy solutions (OGJ, Aug. 13, 2007, p. 80). My family and I are all huge Jason Bourne fans (before he was so cool and so stunningly cast in Damon; we read all the books). I share the sad disillusionment you describe in Damon's behavior and his apparently shallow understanding of the petroleum and synfuels industries (as well as how Congress really works).

As you and OGJ readers know, Damon's behavior only serves to illustrate the pervasive and profound ignorance of the average American in both areas, as well as basic economics. Obviously, major improvements in American fuel efficiency need to be made; however, the market will drive this if the American people begin to grow up: How many of us really need a big truck, a Hummer, a great-room-sized SUV, or a 6,000 sq ft home? Personal responsibility and intelligent consumption, not just legislative mandates, must also play their role.

The simplistic "solutions" Damon (and Ben Affleck, who does not impress me) dramatized, and failing to acknowledge the shortcomings of a "corn solution" taken too far, are enough to make even a die-hard Damon fan question his intelligence (Damon's, not the fan's). The fan in me wants to believe he's smarter than that. A full suite of energy, technology, education, and market solutions is the path to a cleaner, more stable American energy future.

So: Still love the movies, still think he's a brilliant actor, but he needs to become better informed if he is going to dabble in such public activism. Offer to take him to lunch and give him a short course, why don't you?

*Vicki Stamp*
*Petroleum Engineer*
*Casper, Wyo.*

# Calendar

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

OIL&GAS JOURNAL online

Additional information on upcoming seminars and conferences is available through OGJ Online, Oil & Gas Journal's Internet-based electronic information source at http://www.ogjonline.com.

## 2007

## SEPTEMBER

Global Refining Strategies Summit, Houston, (416) 214-3400, x3046, (416) 214-3403 (fax), website: www.globalrefiningsummit.com. 10-11.

PIRA Understanding Natural Gas Markets Conference, New York, 212-686-6808, 212-686-6628 (fax), e-mail: sales@pira.com, website: www.pira.com. 10-11.

Annual LNG Tech Global Summit, Rotterdam, +44 (0) 20 7202 7511, e-mail: anne.shildrake@wtgevents.com, website: www.lngsummit.com. 10-12.

SPE Asia Pacific Health Safety Security Environment Conference, Bangkok, (972) 952-9393, (972) 952-9435 (fax), e-mail: spedal@spe.org, website: www.spe.org. 10-12.

Turbomachinery Symposium, Houston, (979) 845-7417 (979) 845-1835 (fax), e-mail: turbo@turbo-lab.tamu.edu, website: http://turbolab.tamu.edu. 10-13.

Oil Sands Trade Show & Conference, Fort McMurray, Alta., (403) 209-3555, (403) 245-8649 (fax), website: www.petroleumshow.com. 11-12.

EXPOGAZ Gas Congress, Paris, 01 41 98 40 25, e-mail: lberthier@etai.fr, website: www.congresdugaz.fr. 11-13.

European Gas Forum, Paris, 01 41 98 40 25, e-mail: lberthier@etai.fr, website: www.congresdugaz.fr. 12-13.

AAPG Annual Eastern Meeting, Lexington, (859) 257-5500, ext. 173, website: www.esaapg07.org. 16-18.

United States Association for Energy Economics/IAEE North American Conference, Houston, (216) 464-2785, (216) 464-2768 (fax), website: www.usaee.org. 16-19.

API Fall Refining and Equipment Standards Meeting, San Antonio, (202) 682-8000, (202) 682-8222 (fax), website: www.api.org. 17-19.

Annual American School of Gas Measurement Technology Event, Houston, (972) 224-5111, (972) 224-5115 (fax). e-mail: asgmt2007@aol.com, website: www.asgmt.com. 17-20.

IOGCC Annual Meeting, New Orleans, (405) 525-3556, (405) 525-3592 (fax), e-mail: iogcc@iogcc.state.ok.us, website: www.iogcc.state.ok.us. 23-25.

Society of Exploration Geophysicists (SEG) Annual Meeting, San Antonio, (918) 497-5500, (918) 497-5557 (fax), e-mail: web@seg.org, website: www.seg.org. 23-28.

✦Rice Engineering & Construction Forum, Houston, (713) 552-1236, ext. 3, (713) 572-3089 (fax), e-mail: riceglobalforum@theassociationnetwork.com, website: www.forum.rise.edu. 25.

Russia & CIS Petrochemicals Technology Conference & Exhibition, Moscow, +44 (0) 20 7357 8394, e-mail: Conferences@EuroPetro.com, website: www.europetro.com. 25-26.

Annual Engineering & Construction Contracting Association Conference, Colorado Springs, Colo., (877) 484-3322, (713) 337-1644 (fax), e-mail: Twilson@EventsiaGroup.com, website: www.ecc-association.org. 26-29.

Annual Engineering & Construction Contracting Association Conference, Colorado Springs, Colo., (877) 484-3322, (713) 877-8130 (fax), e-mail: registration@ecc-association.org, website: www.ecc-association.org. 27-28.

Russia & CIS Refining Technology Conference & Exhibition, Moscow, +44 (0) 20 7357 8394, e-mail: Conferences@EuroPetro.com, website: www.europetro.com. 27-28.

## OCTOBER

IPLOCA Convention, Sydney, +41 22 306 0230, e-mail: info@iploca.com, website: www.iploca.com. 1-5.

# Dean breaches Campeche

Nina M. Rach
Drilling Editor

Rigs and platforms in US and Mexican waters successfully weathered a Category 5 hurricane in late August. Hurricane Dean, the first of the season, caused preemptive evacuation of some platforms in the Gulf of Mexico and total evacuation of all facilities in Mexico's Bay of Campeche.

When the hurricane season opened in the Gulf of Mexico this summer, a record number of rigs were drilling in US waters 5,000 ft deep or more. In mid-August, Randall Luthi, director of the US Department of Interior's Minerals Management Service, said 15 rigs were actively drilling in deep water. Deepwater oil production facilities include Anadarko's Independence Hub semisubmersible in 8,000 ft of water and Shell and BP's Na Kika semisub in 6,340 ft of water. But US Gulf of Mexico operations have escaped the wrath of the early season weather. Tropical Storm Erin caught the industry's attention in August, spurring evacuations of some offshore personnel (OGJ, Aug. 27, 2007, p. 84). But the storm blew through quickly, making landfall in South Texas and then meandering north.

Dean developed more slowly, keeping drilling contractors and operators on alert. It was listed as a tropical depression on Aug. 13-14, with wind speeds of 30-35 mph, and reached hurricane Category 4 status by Aug. 18. Dean took a direct westward path along the south coast of Jamaica and crossed the southern gulf; its winds reached 140 mph with gusts up to 169 mph—Category 5—just before crossing the Yucatan Peninsula on Aug. 21.

## Mexican rigs

Petroleos Mexicanos had 43 rigs working off Mexico at the time of the August storms, including 29 jack ups, 11 platform rigs, 2 semisubs, and 1 inland barge. The majority were operated by Pride International Inc. (13), Nabors Offshore Corp. (9), Noble Corp. (8), and Perforadora Central (4). Others were managed by Diamond Offshore, Dolphin AS, Hercules Offshore, KCA Deutag, Parker Drilling, Pemex, and Perforadora Mexico.

By Aug. 21, Dean was a Category 5 hurricane, and Noble held a briefing at the company's Sugar Land, Tex. headquarters. Noble's eight jack ups were working primarily in Cantarell oil field in the Bay of Campeche.

Mark Burns, Noble's vice-president and division manager of Noble Drilling (US) Inc., said the company has global positioning system (GPS) units on all its semisubs and jack ups.

Noble uses two web-based tools to monitor storms in real time: ImpactWeather and RigStat. RigStat records data every 5 sec, and Noble gets updates every 15 min, viewable on weather and mooring dashboards.

Noble and Pemex had evacuated about 685 company workers, contractors, and third-party personnel from the rigs in advance of the storm. All told, Pemex evacuated more than 14,000 people and shut in 2.65 million b/d oil and 2.63 bcfd of gas. Pemex has not had an extensive shutdown since Hurricane Roxanne in October 1995.

## Aftermath

Crossing the Yucatan Peninsula tamed Hurricane Dean, which entered the Bay of Campeche as a Category 1-2 hurricane with wind speeds less than 100 mph.

Companies began repopulating offshore rigs and platforms in the US Gulf of Mexico. By Aug. 25 Noble had restaffed five jack ups in the US gulf, and by Aug. 26 it had repopulated the eight rigs in the Bay of Campeche. On Aug. 28, the company announced that the rigs in Mexico had not been damaged in the storm.

Pride evacuated its Mexico-based jack ups and platform rigs before the storm and announced on Aug. 27 that it had reboarded start-up crews, found no damage, and expected to resume operations that week.

Noble's Burns said the overall cost of Erin and Dean to the operators would take a while to quantify, but figuring the cost of evacuations was simpler. There are 500-550 helicopters operating in the Gulf of Mexico. About half of them are single-engine models, capable of carrying 4-6 people. Burns said Noble generally does not use single-engine aircraft. The other helicopters are twin-engine units, but only 20 of these are Noble's preferred Sikorsky S92 model, which carries 18 people. Twin-engine helicopters lease for about $40,000/day.

Burns estimated that the gulf evacuation, using all available helicopters, required at least 3 days at a minimum cost of $3-5 million. Add to this the additional transportation and housing expenses, lost time on projects, and a few weeks of rig day rates, and the overall cost is tens of millions of dollars (and even more pesos). ✦

Editorial

# Alberta's royalty review

Months of uncertainty for Canada's oil sands industry soon will end. That's the good news. How uncertainty over the Albertan fiscal regime will end remains, well, uncertain. And that could be bad news far outside the region that leads the world in production of bitumen and synthetic crude oil.

Last February, Alberta Premier Ed Stelmach formed an independent panel to study the royalty and tax regime "to ensure Albertans are receiving a fair share from energy development through royalties, taxes, and fees." Initially, the panel was to make its final report by Aug. 31. The web site of the Alberta Royalty Review Panel now says recommendations will go to the government by mid-September.

## Producers worry

Except where participation terms are onerous and can only improve, producers worry when governments talk about adjusting fiscal regimes. Production investments expose capital to heavy risk for a long time and are sensitive to, among other things, the rates and timing of payments to governments.

For Alberta's burgeoning oil sands industry, hints of change come at a bad time. Capital and operating costs, which technology had lowered impressively, have spurted lately in a development boom. Profit margins, never lavish in a business with high production costs and low product values, are feeling the squeeze. And the industry faces new uncertainty from federal regulations under development covering emissions of greenhouse gases.

The provincial government knows what's at stake for Alberta. A fact sheet from the review panel notes the province collected a record $14.3 billion (Can.) from nonrenewable-resource activity in the 2005-06 fiscal year—nearly 40% of all provincial revenue. It projects nonrenewable-resource receipts in 2006-07 of $11.7 billion. Of that, $3.7 billion will be from oil sands royalties and lease bonuses. The panel also acknowledges that bitumen from oil sands will claim a growing share of future production as conventional oil and gas output declines.

In the system under review, producers pay lease bonuses and rentals plus royalties that vary by production type. For conventional oil and gas, the royalty rate depends on variables that include vintage, well productivity, and commodity price. In 2005, average royalty rates were 15% of production for conventional oil and 20% for gas. For oil sands, the royalty rate is 1% of gross revenue until a project recovers invested capital plus a financial allowance. After payout, the royalty rate is the greater of 25% of net revenue or 1% of gross revenue.

According to speculation, the review panel might propose an increase of a percentage point or two in the oil sands royalty rate, possibly accompanied by an easing of the bite on conventional production. Such a change probably would delay some oil sands projects, perhaps permanently. Labor and material shortages already hamper oil sands work. Further delays might poison the economics of some projects.

More important than immediate effects on current plans, however, would be the appearance that Alberta used price elevation as an excuse to grab money. Precedents like that chill investment. The government might avoid trouble by leaving the royalty rate alone and focusing instead, if it must change anything, on how rising costs hurt it along with producers by extending payout periods.

## Beyond Alberta

Alberta's royalty reform is important well beyond provincial borders. Canada isn't the only place with unconventional oil. It just has a larger identified heavy-oil resource and produces more bitumen than any other country. It thus leads the world in finding solutions to problems heavy-oil producers elsewhere eventually must face, such as lowering inputs of energy—especially natural gas—and water, handling wastes and byproducts, and controlling emissions of greenhouse gases.

Producers should have no quarrel with Stelmach's assertion that "Albertans must be confident that the royalty structure will meet the needs of the province." Indeed, if that confidence has weakened then the royalty review is much in order. But there's more at stake than loonies in the treasury. The oil sands of Alberta aren't just yielding bitumen; they're generating knowledge and know-how crucial to future supply of affordable energy. In that, everyone on Earth has an interest. ✦

# Part 2—Refining dynamics counter public misperceptions

*Carol Dahl*
*Rachel Hackney*
*Anthony Scott*
*Colorado School of Mines*
*Golden, Colo.*

*This article continues the explanation for recent gasoline price increases and other dynamics of the gasoline market that began last week (OGJ, Sept. 3, 2007, p.18). Part 1 examined public misconceptions, gasoline price history, and the effects of supply, demand, and refiners' costs on profits.*

Some have argued that refiners' recent high income levels are excessive. However, oil refining is a highly capital-intensive industry needing large profits to compensate companies for huge investments. Thus, it is important to put these profits in the context of returns on investment (ROI) compared with other investment opportunities.

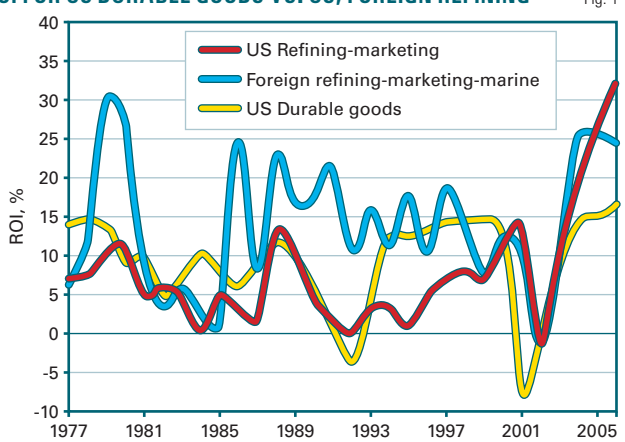
The rates of return on fixed investment in US and foreign refining were calculated as the ratio of net income to property, plant, and equipment, or noncurrent assets, from data reported to the Energy Information Administration by Financial Reporting System (FRS) companies. Fig. 1 shows the ROI for US and foreign refining and US durable goods during 1977-2006.

The figure clearly shows the inadequate US returns of the 1990s. Domestic refining has earned a consistently lower ROI than foreign refining, with higher returns shown in only 3 years during 1977-2002. Only in 2006 did US domestic refining returns surpass foreign refiners' high ROI of 30% earned in 1980. Over the whole period, ROI for the companies earned from foreign refining averaged more than 13%, almost double that for US refining.

Fig. 1 compares the ROI in US refining with the ROI in the US durable goods industry, which was chosen for comparison because it is a capital-intensive industry that does not include petroleum, and data were available through 2006.

Over the 28-year period 1977-2006, the US durable goods industry earned a 9.4% average ROI, compared with 7% in refining, while at the same time having a lower variability in rates of return. After the 1992 recession, refining struggled to return to historical ROI levels, while durable goods rebounded much more quickly. Even in 2001, after a decade of cost-cutting, consolidation, and restructuring, US refining had not approached the peak ROI being earned in US durable goods. Durable goods returns fell dramatically in 2001, and refining followed in 2002. Only since 2004 has a strong market provided returns in US refining and marketing that exceed the 1990 highs earned in the durable goods industry.

**ROI FOR US DURABLE GOODS VS. US, FOREIGN REFINING*** Fig. 1




*For EIA's Financial Reporting System companies, 1977-2006.
Sources: Colorado School of Mines, American Petroleum Institute

## Capacity and investment

Some industry critics emphasize the number of refinery closures in the US and assert that these closures were a deliberate attempt to curtail capacity and increase monopoly power. In fact, the refineries that closed were too small or old to be competitive. Many were originally built to take advantage of oil quotas or price controls that ended in the early 1970s and early 1980s, respectively, and were not viable economically without them.

There were many mergers in the years 1998-2001, with capacity increases averaging 1.7%/year. In 1999, capacity increased by about 650,000 b/d, the largest annual increase since 1974. Between January 2004 and January 2006, refinery capacity increased by 1.4%/year, more than the average rate of increase since 1994. This higher rate of expansion continued despite almost flat total oil product consumption in

2005 and falling total product consumption in 2006.

In addition to investing in new total capacity, US refineries have made heavy investments in coking and hydrotreating, enabling them to make cleaner fuels and take advantage of the increasing price spread between lighter sweet crudes and heavier sour crudes. Although capacity at existing refineries has expanded, no new US refinery has come on line in decades. Two attempts to build new refineries were abandoned in the 1970s after years of battles with regulators, and a planned refinery in Arizona has been 6 years in the permitting process and is unlikely to be completed before 2011, if ever.

While capital investment has not increased as fast as profits, this historically is consistent with other capital-intensive industries, where capital spending is always more stable than profits.

Changes in profits tend to feed back to investment over 3 years because investments take time to plan and implement and must follow long-term demand trends.

On three occasions before 2003—in 1979-80, 1988-89, and 2000-01—the ROI in refining exceeded the 9.4% long-term average return in durable goods manufacturing. In all cases, refiners increased capacity in the same or the following year. In every case, the capacity changes were more muted than the increase in profits, and in every case, profit rates fell to record lows within 1-4 years after the higher investments in new capacity.

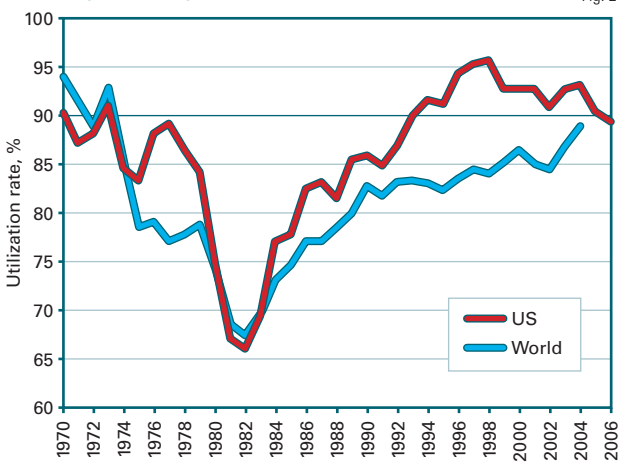
## Capacity utilization

Some of the growth in US gasoline demand has been met by better use of capacity. The optimum rate of capacity utilization in the US is considered to be 90-95%, with a 95% utilization rate considered to be full capacity because refineries are likely to be hitting process bottlenecks. Rates below 90% suggest that many units are down for maintenance or that refining margins are so depressed that capacity is being taken off line.

Fig. 2 displays capacity utilization rates in US and worldwide refining since 1970. For most of the last 3 decades, refinery utilization rates in the US have been higher than in the rest of the world. The graph clearly shows the excess capacity and low utilization rates that developed in the 1970s when rising gasoline prices and recession reduced gasoline consumption.

Utilization in the US recovered slowly until 1998, when it peaked at 95% before returning to around 90% through 2002. Then it jumped to about 93% in 2004, with summer peaks even higher. Summer peaks in 2005 exceeded 95%, but annual utilization was lower because of temporary outages from hurricanes Katrina and Rita. In 2006, overall capacity utilization fell to 90%, but summer utilization only fell slightly to 93%. High unplanned outages in the spring of 2007 have put utilization rates lower than normal for this time of year.

**REFINERY UTILIZATION RATE** Fig. 2




Sources: Colorado School of Mines, American Petroleum Institute

## Capacity from imports

Because gasoline and other oil products are part of a world market, imports can often offset domestic capacity shortfalls. About 80% of the world's total refining capacity is outside the US. Foreign refineries have slightly lower utilization rates, and about 90 small refineries have closed since 2000. Foreign refineries have faster capacity growth than US refineries, however, with an especially big jump in 2006. This faster capacity growth was driven by accelerated growth in petroleum product consumption worldwide.

Although US gasoline and blending stock imports are small relative to the total market, they have increased at an annual average rate of more than 9% between April 2000 and April 2007. The imports are a combination of finished gasoline and gasoline blending stocks, with the latter growing more than three times faster because of the different US gasoline specifications and the phaseout of methyl tertiary butyl ether. The majority of imports come into the East Coast and the Gulf Coast regions.

## Refining margins

The major driver of profits from refining is refining margins, the spread refineries earn on each barrel of refined petroleum. Beginning in 2004, exceptional US income growth and capacity constraints induced by hurricanes and uncertainties in environmental regulations forced refineries to push equipment to its limits to increase output. Even so, supply was insufficient to satisfy the market's thirst for clean summer fuels, causing prices to rise in order to allocate the limited available capacity. These price increases produced exceptional profits in US refining.

Refinery margins tend to show the same general pattern across all the reported regions except for Southeast Asia (Fig. 3). The claim that refinery profitability is lower overseas is true of Southeast Asia, which has less sophisticated refineries that are distant from

the US market. California's stringent fuel requirements have kept margins considerably higher except during the weak markets of 2002.

But in northwestern Europe, margins very closely track those on the US East Coast, and margins there have not varied by more than 4¢/gal. The Midwest and Gulf Coast also track each other but not as closely, with margins up to 6¢/gal difference. Both margins jumped considerably with the hurricanes of 2005, but in 2006 margins were lower along the Gulf Coast, which has more imports (Fig. 3).

Monthly data show the same pattern across regions, but margins do not track as closely because of the transport time it takes to arbitrage across the various markets. Real margins through May of 2007 are similar to those through May of 2006 except for a spike in the Midwest where margins in May—at 34¢/gal—were more than double those of last year and even exceeded those in California for the first time.

The US Federal Trade Commission, which monitors gasoline prices on a daily basis to watch for monopoly behavior, attributes the current high prices leading to these margins to strong gasoline demand, unplanned outages, and lower imports (see article, p. 22). FTC attributes the lower imports to strong gasoline demand in Europe and Asia.

The current higher profits follow a decade when refining was acutely depressed. Although the restructuring and cost-cutting of the 1990s returned domestic refining to viability, they did not create sufficient market power to protect the industry from the market downturn of 2002 when refining losses were the largest since 1977.

## Gasoline inventories

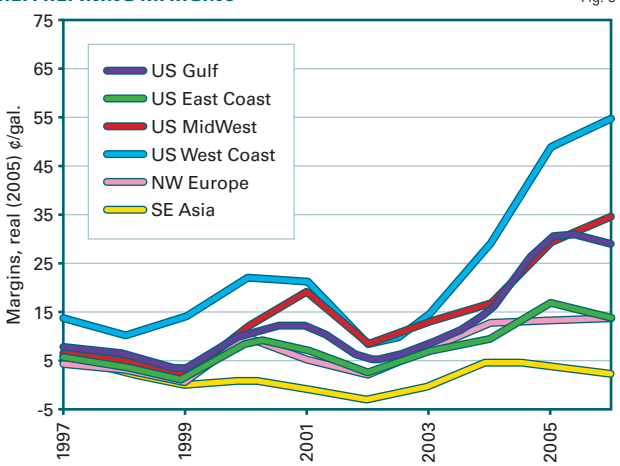
Critics of US refiners have argued that during the period 1990-2005, when gasoline product prices increased by 20%, gasoline stocks fell 6% and that this reduced buffer can cause price run-ups even during small market disruptions such as normal spring maintenance operations.

Gasoline inventories have indeed been declining, not just since 1990, but since 1980.

One might expect the decline in inventories to increase gasoline price volatility. Yet, although gasoline price volatility has been generally trending up, current volatility levels are actually less than in the years 1979-92, when inventories were higher. The volatility in those years is explained by the more-volatile price of crude oil, which was shown in Part 1 to be the major determinant of gasoline prices. Comparing the inventory-to-sales ratios for gasoline, oil products, and manufacturing as a whole shows a parallel pattern of declining inventories. These parallel trends suggest that the trend in oil inventories was driven by the evolution of leaner manufacturing practices throughout US industry, rather than by activities specific to the oil industry.

## AREA REFINING MARGINS

Fig. 3




Source: Muse Stancil & Co.

## Market concentration

During 1998-2002, as many as 14 oil companies merged into 7. The perception is that these mergers and acquisitions increased concentration and market power in refining. However, the evidence suggests otherwise. In 1996, only 16 large companies owned and operated 65% of US refinery capacity, but by 2001 their share had fallen to 44%. The percentage of refineries held by the top eight firms fell by almost 10% during 2002-05, suggesting that entry into this industry is not so difficult.

One reason for declining concentration has been the move by major oil companies away from vertical integration by spinning off less-profitable refining assets to concentrate on production. Shifts towards high-volume gasoline stations and increasing hypermarket sales are also believed to have increased competition within the industry.

## Futures markets role

What role, if any, does the futures market play in elevating gasoline prices?

Critics argue that speculation in financial commodity markets has bid up the gasoline futures price, which in turn has bid up the gasoline spot price. Gasoline futures contracts typically are used to lock in prices. More than 99% of contracts do not go to delivery, and many traders who are not in the gasoline business purchase contracts hoping to make a profit.

Between fall 2003 and 2005, gasoline futures activity increased to levels not seen since 1993. Historically, about 90% of futures contracts have been held by hedgers or commercial traders in the oil industry, with speculators or noncommercials not in the oil industry holding about 10%. In 2003-05, however, the ratio of noncommercial contract holders doubled to 20%, and most of this increase was in buying contracts (going long).

Critics argue that the actions of these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speculators have destabilized the market. Others have claimed that speculators bid up prices by going long in futures. Most economists, however, believe that noncommercials help provide liquidity to the market and allow commercials to shed risk, thereby stabilizing the market and providing advance signals about capacity needs. This would suggest that the increased volume of 2003-05 reflected increased uncertainty that drove both hedgers and speculators into the market to transfer risk.

Theoretically, futures and spot markets are linked as follows: If futures prices rise relative to the spot price, commercials buy spot for inventory (bidding up the spot price) and sell futures contracts (pushing their prices down). The commercials sell off the inventory in the future, lowering future spot prices. Conversely, if futures prices fall, traders sell gasoline out of inventory at the current higher price and buy futures contracts at lower prices. When traders are right, they reallocate inventories to periods of increased shortage and signal refiners when to increase capacity.

Investors are destabilizing only if they are wrong. If investors erroneously expect shortages, then increased inventories today will bid up current prices but cause inventories to be sold at lower prices in the future when no real shortage exists. Although this scenario is possible, it is unlikely to persist for long. Investors who destabilize the market must buy high and sell low, thus losing money. Being wrong in such a game is costly, and market fundamentals quickly reassert themselves.

Alan Greenspan, former chairman of the Federal Reserve, asserts that investors and speculators have correctly identified impending shortages and are "hastening the adjustment process" in world oil markets. Academic studies suggest that the introduction of derivatives reduces price volatility, increases the speed at which markets incorporate adjustment, and may decrease the bid/ask spread.

A study by the Commodity Futures Exchange Commission in 2005 found no link between speculation by hedge funds and money market traders and price changes. They concluded that underlying fundamentals, not speculation, were determining prices.

Gasoline prices may also feed back to crude oil prices. Increasing gasoline demand can bid up gasoline prices, increase crude oil demand, and increase crude oil prices. Such a pattern is consistent with a market-based increase in gasoline prices. Many argue that monopoly power has led to high gasoline prices, which have led to higher crude prices. This argument, however, is logically inconsistent. If higher gasoline prices had been caused by monopoly suppliers withholding capacity, this would have had the effect of reducing gasoline consumption and crude oil demand, thus reducing the price of crude oil.

### Market elasticities

When refineries are nearing capacity, gasoline consumption and production are both unresponsive to price in the short run. There is some evidence that this responsiveness has become smaller than it was in the 1970s. This means that small shifts in demand or supply have large short-term effects on prices as shown in the monthly data for gasoline price and product supplied. It does not mean that such markets are not competitive or contestable in the long run.

The consumer response to prices is more than 10 times as great in the long run, when consumers may move closer to work, drive less, or buy more fuel-efficient vehicles and hybrids.

Rapidly increasing gasoline imports suggest that foreign refineries provide competition, and the rise of large independent refiners in the US suggests that barriers to entry are not high. Renewable fuels in the form of biodiesel and ethanol may provide some competition, but can only be a significant factor if they are not made from food crops.

### Evidence

The simplistic but appealing explanation that mergers, monopolies, and speculators have caused recent high gasoline prices and profits is not supported by statistical evidence. The real reasons have been high crude oil prices, higher operating costs, proliferating grades of gasoline, unexpected demand growth, recovery from low and negative ROI rates in the 1990s, hurricanes, and regulatory uncertainty. Further, the evidence suggests that the higher profits have been accompanied by normal inventory and investment practices.

A recent assertion that refinery capacity should be increased by more than 15% is also not supported by the evidence and would surely lead to the pattern of overcapacity and losses that followed the price increases of the 1970s.

### Acknowledgment

The research for this article was supported by the American Petroleum Institute. For complete bibliographic references and statistical support, see http://dahl.mines.edu/api.pdf. ✦

# FTC: Market factors explain '06 gasoline price spurt

**Nick Snow**
*Washington Correspondent*

Market factors ranging from reduced refining capacity to higher crude oil and ethanol prices led to dramatically higher gasoline prices in the late spring and early summer of 2006, the US Department of Justice's antitrust division and the Federal Trade Commission jointly concluded on Aug. 30.

Growing demand as the 2006 summer driving season approached, reduced refining capacity lingering after Hurricanes Katrina and Rita in 2005, further reductions in processing capacity as refiners switched to ethanol from methyl tertiary butyl ether, higher

prices for ethanol and crude oil, and higher-than-expected demand during summer pushed up prices, the agencies said in their report to US President George W. Bush.

The determination that the higher prices resulted from these factors supports a conclusion that no antitrust laws were broken, they added. The FTC voted 4-1 to issue the report, with Commissioner Jon Leibowitz dissenting.

The report said about 75% of the spring and summer 2006 national average gasoline price increases resulted from growing demand leading into the summer driving season and increased crude oil and ethanol prices.

"The evidence further indicates that the remaining 25% of the price increases stemmed from declines in the production of gasoline—due to refiners' transition to ethanol from other blending components, persistent refinery damage related to Hurricanes Katrina and Rita...and other refinery outages caused by unexpected events and required maintenance—coupled with increased demand," it said.

While the FTC's staff would not rule out other factors, it believed the causes it cited "adequately explain the 2006 price increases." It said, "Our targeted examinations of major refinery outages revealed no evidence that refiners conspired to restrict supply or otherwise violated the antitrust laws."

In his dissent, Leibowitz conceded that FTC staff members identified some plausible justifications for the gasoline price increases. But he warned that the oil industry, "which posted record profits in 2006," should not consider the report vindication for its behavior. "The question you ask determines the answer you get. Whatever theoretical justifications exist don't exclude the real world threat that there was profiteering at the expense of customers," he said.

A congressional critic of the FTC's gasoline price oversight approach immediately criticized the report. Bart Stupak (D-Mich.), who chairs the House Energy and Commerce Committee's Oversight and Investigations Committee, called the findings "further proof that the Bush administration will ignore the evidence and distort the facts to protect big oil companies."

Stupak, whose bill aimed at ending alleged oil product price-gouging passed the House earlier this year, said he would continue working with other members of Congress to send such legislation to Bush's desk. "The fact remains that last year, when [the FTC] examined price-gouging under definitions supplied by Congress, the commission found evidence of gouging by refiners and other big oil companies," he said.

A May 2006 FTC report of price increases following Hurricane Katrina in September 2005 noted 15 instances involving seven refiners, two wholesalers, and six retailers of "price-gouging" under a narrow definition in a 2006 appropriations bill. According to that definition, "gouging" occurred if the average gasoline price in the hurricane-afflicted area was higher after the storm than it was before (OGJ, June 5, 2006, p. 23).

The FTC made clear in its 2006 report that "other factors, such as regional or local market trends, appeared to explain the pricing of these firms in nearly all cases." ✦

# Nigeria to restructure energy industry under new policy

**Uchenna Izundu**
*International Editor*

Nigeria is radically restructuring state-owned Nigeria National Petroleum Corp. and the Nigerian energy sector under a new oil and gas policy that will take 6 months to implement.

An NNPC spokesman told OGJ the aim of the restructuring was to improve the commerciality of the company in its new state. "The government is looking to loosen its ties so that it becomes internationally integrated to be like Petrobras, Petronas, and Statoil," he said.

Undergoing major changes are the Department for Petroleum Resources (DPR), the Ministry of Petroleum Resources, and the Petroleum Products Price Agency, which regulates domestic pump prices.

A national energy council, led by Nigeria's President Umaru Yar'Adua, will spin out five separate units from NNPC with separate and autonomous functions to reduce corruption within the country's oil industry:

- National Petroleum Co. of Nigeria (Napcon), which will replace the current NNPC, will have seven directorates, including upstream, refinery and petrochemical, marketing and investments, gas and power, engineering and technology, finance and accounts, and corporate services, said NNPC.

Napcon will be awarded oil and gas blocks in Nigeria to put the energy industry under domestic control rather than having dominant international operators such as Royal Dutch Shell PLC operate the blocks. It also will aim to increase Nigeria's refining capacity to 1 million b/d from 445,000 b/d over the next 5 years.

In NNPC's current format, it works with foreign partners to produce oil but also imports fuel and has regulatory and administrative duties leading to confusion and conflicts of interest. It has faced many accusations of corruption and mismanagement.

- National Petroleum Directorate (NPD) will replace the existing Ministry of Petroleum, said the newly appointed Minister of State for Petroleum Odein Ojumogbia.
- Petroleum Inspectorate Commission (PIC) will replace DPR, which polices the oil industry as a depart-


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ment within the ministry of petroleum. "[PIC] will be an autonomous body that would perform [DPR's] oversight functions," Ojumogbia said. DPR will be scrapped.

- Products Distribution Authority (PDA), a new body, will replace the Pipeline Products Marketing Co., he said.
- National Oil & Gas Assets Holding Co. (NOGAHC) will replace NNPC's frontier exploration services arm, Napims [National Petroleum Investment Management Services], to handle the management of assets of the former NNPC, added Ojumogbia.

### Doubts surface

However, Nigerian oil companies, wondering whether the changes will be effective, stress that the government must leave these new agencies to run independently if they are to differ from NNPC.

Andrew Hayman, director of industry relations at IHS Consultancy, said the reforms were welcome if they lead to improved efficiency in joint venture operations and more application of the government's share of financing of oil operations. He told OGJ that operators such as Shell have said they were unable to fulfill their operations because of a shortage of government funds.

The policy reforms were approved at the last meeting of the Federal Executive Council in late August.

The government's action follows reports published in 2000 by the Oil and Gas Industry Reform Committee and the National Council on Privatization, which proposed new operational models for the energy ministry and NNPC. ✦

## Australia awards 11 offshore exploration permits

**Uchenna Izundu**
*International Editor*

Total E&P Australia, Samson International (Australia) Pty. Ltd., and CNOOC Australia E&P are among companies acquiring 6-year exploration permits in Australia's latest licensing round. The permits can be renewed twice for periods of 5 years.

Australia has granted 11 offshore exploration permits to nine oil companies, which are expected to generate exploration programs worth more than $800 million (Aus.) over the next 6 years.

Australia's resources minister, Ian Macfarlane, said the high number of bids, 21, showed that companies are interested in Australian offshore petroleum exploration. The areas are in

commonwealth waters off Western Australia, Tasmania, and Northern Territory and include four permits in designated frontier areas (DFAs).

The government has offered tax incentives to companies exploring in the DFAs.

Samson acquired two permits in the Northern Arafura basin off Northern Territory. Santos Offshore Pty. Ltd. received a permit in the Sorell basin off Tasmania. In the Bonaparte basin off Western Australia, permits went to CNOOC Australia, Total Australia (two permits), Goldsborough Energy, and Reliance Industries Ltd.

Australia granted three permits in the Carnarvon basin off Western Australia, one to Woodside Energy Ltd. and Hess Exploration (Carnarvon) Pty. Ltd. and two to Gerald Nelson.

## Work programs

Applicants were required to nominate a guaranteed minimum dry-hole exploration program for each of the first 3 years of the permit term and a secondary program for the remaining 3 years, the Australian Resources Ministry said.

Samson will shoot 1,400 km of 2D seismic survey and conduct geotechnical studies over Permit NT/P74 in the Northern Arafura basin. The work is expected to cost $2.78 million (Aus.). Under the secondary program, the company has committed to drill two exploration wells and shoot a 400 sq km 3D seismic survey at an estimated cost of $33 million.

For Permit NT/P75, also in the Northern Arafura basin, Samson will invest $4.18 million shooting a 2,200 km 2D seismic survey and conducting geotechnical studies. It plans to drill two wells and shoot 700 sq km 3D seismic survey, which will cost an estimated $35 million.

Santos will spend $2.2 million on gathering 700 km of 2D seismic data and conducting geotechnical studies for Permit T/48P in the Sorell basin. The secondary work program consists of one well, geotechnical studies, and a 300 sq km 3D seismic survey, which will cost an estimated $35.9 million.

Gerald Nelson will reprocess 227 km of 2D seismic data covering Permit WA-400-P in the Carnarvon basin. Nelson will shoot a 40 sq km 3D seismic survey and do geological studies, which will total an estimated $1.29 million. Nelson later will drill two exploration wells and shoot a 40 sq km 3D seismic survey.

For Permit WA-401-P, also in the Carnarvon basin, around 104 km of 2D seismic data will be reprocessed. Nelson will spend $1.4 million on this, geotechnical studies, and a 45 sq km 3D seismic survey. Nelson will drill two exploration wells and acquire 45 sq km more 3D seismic data.

Total will reprocess 1,000 km of 2D

seismic data for Permit WA-402-P in the Bonaparte basin. It will also do geotechnical studies, and acquire and interpret 754 sq km of 3D seismic data under a $13.2 million work program. Total will spend $59.4 million drilling one exploration well and doing geotechnical studies.

For Permit WA-403-P Total will acquire and interpret 1,984 sq km of 3D seismic data and carry out geotechnical studies. It will also drill two exploration wells, all of which are expected to cost $144.4 million. The secondary work program consists of geotechnical studies at an estimated cost of $7.2 million.

Total's Block WA-402P covers 5,150 sq km, and WA-403P spans 5,685 sq km. The blocks are 200 km offshore in 100 m of water. Exploration of the blocks is scheduled to begin in 2008.

Woodside Energy and Hess Exploration (Carnarvon) beat four other companies to secure Permit WA-404-P in the Carnarvon basin. "The companies proposed a guaranteed work program of 2,748 sq km 3D survey, geotechnical studies, and nine exploration wells at an estimated cost of $196.2 million. The secondary work program consists of geotechnical studies and one exploration well at an estimated cost of $21.8 million," the Australian Resources Ministry said.

Reliance Industries picked up Permit WA-405-P in the Bonaparte basin and plans to reprocess 3,200 km of 2D seismic data and carry out geotechnical studies. It will also acquire 500 km of 2D and 600 sq km of 3D seismic data, all of which will cost an estimated $9.6 million. The secondary work program consists of geotechnical studies and one exploration well at an estimated cost of $20.16 million.

### Other permits

CNOOC Australia trumped two other companies for Permit WA-406-P in the Bonaparte basin. The company plans to shoot 400 sq km of 3D seismic survey, execute geological studies, and drill five exploration wells for $81.3 million. CNOOC, under the secondary work program, will spend $80.8 million on 400 sq km of 3D seismic survey, geological studies, and five exploration wells.

Goldsborough Energy won Permit WA-407-P in the Bonaparte basin and committed to conducting geotechnical studies and shooting a 1,400 km of 2D seismic survey. It will also reprocess 2,000 km of 2D seismic data, all of which will cost $2.75 million. For the secondary work program, it will interpret seismic data, conduct geotechnical studies, and drill one exploration well for an estimated $15.6 million. ✦

# Ireland revamping fiscal regime for offshore licenses

**Uchenna Izundu**
*International Editor*

Ireland is revamping its fiscal and licensing regime for oil and gas and soon will invite operators to bid for Porcupine basin blocks on its challenging Atlantic margin.

The government has added a "profit resource rent tax," graded according to profitability, to the 25% corporate tax already in effect. Changes apply to licenses awarded after Jan. 1, 2007.

Grades for the new tax depend on "profit ratio," defined as "rate of profits less 25% corporate tax divided by the accumulated level of capital investment."

On licenses where the profit ratio is less than 1.5, there will be no change in the tax rate beyond that of the corporate tax. The tax rate will increase by 5% where the profit ratio is 1.5-3.0, by 10% for 3.0-4.5, and by 15% for more than 4.5.

The government also is reducing the lengths of some licenses, requiring operators to surrender acreage earlier than before, increasing all fees in line with the consumer price index, and reducing the confidentiality period on data acquired by license-holders and furnished to the Department of Communications, Energy, and Natural Resources.

Only 23 wells have been drilled in Ireland under the previous fiscal regime introduced in 1992. Energy minister Eamon Ryan, said, "The difference now is in prospectivity, price, and profitability." Previously, Ireland has been known for having low taxes.

Ryan noted improved seismic technology, the availability of data, and high energy prices over the past 15 years.

The period of deepwater licenses will fall from 12 years to 9 years, and the minimum period for a frontier license will be reduced to 12 years. At the end of the first phase of all exploration licenses, operators will also be automatically required to give up 50% their acreage and surrender a further 50% at the end of the second phase of deepwater and frontier licenses, regardless of drilling commitments.

The confidentiality period for data submitted to the government will decline to 4 from 5 years.

The Irish energy department stressed that work programs for the licenses must give time schedules but added that there is no change in drilling obligations for standard and frontier exploration licenses. However with deepwater licenses, companies must drill wells earlier. The first well must be drilled in the first 3 years of the license (4 years at present) and a second well by the end of the 6th year (8th year at present).

Under the revamped licensing regime, operators must submit a development plan within a year of signing the petroleum lease instead of 2 years at present.

Details of the licensing round will be published in the EU Official Journal this month.

A spokesman from the Irish energy

WATCHING THE WORLD

Eric Watkins, Senior Correspondent

# Japan seeks oil worldwide

Japan's July crude oil imports by refiners and trading houses rose 7.1% from July 2006 to 21.3 million kl, or 4.32 million b/d.

While the refiners and trading houses' crude imports from the Middle East accounted for 85% of overall imports in July, those imports were actually down 7.6% from July 2006 and down from 86.1% in June.

Reduced dependence on Middle Eastern supplies? While the amount is not huge, it still makes for an interesting story, due to the fact that Japanese oil companies are going to places much farther afield to obtain their supplies.

Consider the efforts of Japan's Teikoku Oil, a wholly owned subsidiary of oil exploration company Inpex Holdings, which Aug. 31 said it acquired a 35% participating interest in Block 31, which covers 13,860 sq km in the Guyana basin in 20-130 m of water off Suriname.

## Oil in Suriname

Will the block yield oil? That remains to be seen as a 3-year exploration period, which includes a drilling commitment, will begin in May 2008.

But the Japanese firm—which already operates in Brazil, Mexico, and Venezuela—is upbeat about the prospects. "We think this new deal in Suriname may lead to further opportunities to expand our business in the Latin America region," Teikoku said.

The firm is moving ahead with plans to explore in the region as shown on Aug. 27 when Colombia's state hydrocarbons regulator ANH distributed a list of prequalified operators for the upcoming Ronda Caribe round for 13 exploration and production blocks.

In fact, ANH preapproved just three companies as operators: Colombia's state-owned Ecopetrol, Chevron Corp., and Teikoku. That's saying something, too, as the competition includes some internationally known heavy-hitters.

## Oil in Mexico

Teikoku also is at work in Mexico, a point revealed Aug. 10 when Brazil's Petroleo Brasileiro SA (Petrobras) and Mexico's Petroleos Mexicanos signed two agreements to develop Mexico's oil reserves.

The agreements foresee joint studies aimed at developing heavy oil production processes in shallow waters and at oil production in fractured carbonated reservoirs.

Petrobras currently leads the PTD consortium, which renders services in the Burgos basin in northern Mexico. The consortium is formed by Petrobras 45%, Teikoku 40%, and Mexico's Diavaz 15%.

Not all of Teikoku's discoveries are huge, however, nor are all of them outside of Japan. Just last month Teikoku discovered oil and gas deposits at an exploratory well in the northern Japanese prefecture of Niigata.

Flow tests conducted since May have seen the well producing 80 kl./day of oil and 7,000 cu m of gas, from 3,588-3,702 m below the surface.

The project will continue to assess the total size of the deposits, Teikoku said.

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ministry told OGJ it was unclear how many blocks would be offered. Earlier this year, the energy ministry said it expected to award acreage covering 63,500 sq km in the basin. Five exploration wells have been drilled in the Porcupine basin area over the last 20 years. ✦

# Saskatchewan holds first oil sands rights offering

Saskatchewan, which holds oil and gas sales six times/year, held its first public offering of oil sands rights at its Aug. 16 sale. The auction for all oil and gas rights raised about $38 million, including $3.3 million for six oil sands exploration licenses.

Until the August sale, companies looking for oil sands were not required to pay for an exploration permit.

In a news release, Government Relations Minister Harry Van Mulligen called the sale historic and said it "heralds the beginning of a potential new oil sands industry in Saskatchewan."

Three Calgary-based companies bid successfully for oil sands permits. Oilsands Quest Inc. has been exploring in Saskatchewan's northwest corner for several years and Petroland Services Ltd. was the highest bidder for an oil sands exploration license, paying $1 million (Can.) for about 9,000 ha of land north of the Clearwater River in northwestern Saskatchewan. Cavalier Land Ltd. also won oil sands exploration permits on land in the northwest area of the province.

## Oilsands Quest

Oilsands Quest reported July 12 that its previous oil sands discovery at Axe Lake and other previously acquired, contiguous oil sands exploration permits in northwest Saskatchewan and northeastern Alberta hold a resource potential of about 10 billion bbl of bitumen.

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Kuwait is the Persian Gulf's fourth largest oil producer and maintaining momentum to raise production capacity from around 2.6 million barrels a day to 4 million by 2020. The government is preparing to outline plans for the $ 9bn "Project Kuwait" upstream opening by the end of June. In comments reported by the Kuwait News Agency in April, the oil minister said the oil ministry would come up with a project outline within a couple of months. "Project Kuwait" is intended to use international oil company (IOC) investment to double oil production at five northern fields to around 0.9m b/d.

The oil minister says, the state owned refinery operator Kuwait National Petroleum Company (KNPC) had revised its budget estimates for the Al-Zour refinery to $ 12bn, up from the original budget of $ 6,3bn. The 600 m b/d refinery at Al-Zour is intended to provide clean fuel for power generation.

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BASRA INTERNATIONAL FAIR

That includes the company's estimate of original bitumen in place (OBIP) for the Axe Lake discovery on its Saskatchewan permits "and resource potential on certain portions of the remainder of its Saskatchewan permits and its adjacent Alberta permits."

An independent consultant's estimate of OBIP for Axe Lake will be completed in the fall, but the company's estimate includes a total potential bitumen resource of 2.1-2.8 billion bbl plus another 3 million bbl for selected areas south and northeast of the Axe Lake discovery area. The remaining 4.5 billion bbl was said to be resource potential for about two townships of the company's adjacent permits in Alberta.

"Axe Lake is proving to be suitable for in situ recovery," Oilsands Quest said. High recovery factors include thick, continuous, coarse-grained oil sands with high permeability and porosity in reservoirs at depths of 185-205 m.

Quest is awaiting approvals to continue its exploration program, but meanwhile is evaluating drilling data, performing laboratory studies for bitumen recovery, conducting environmental programs to facilitate regulatory approvals, developing engineering timelines to the field pilot plant stage, and conducting economic feasibility and risk assessment studies.

This quarter it plans to begin drilling in Saskatchewan and conducting seismic surveys in adjacent Alberta. In the fourth quarter it will undertake reservoir modeling and continue drilling in Saskatchewan and Alberta in the winter.

In 2008, it plans to drill test wells to confirm laboratory studies in the first quarter, establish a data room and initiate joint venture partnership negotiations for Axe Lake development in the second quarter, and start field pilot production in the fourth quarter. ✦

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# Size distribution of Middle East fields and reserves growth issues draw focus

**Louis Christian**
*Exploration Consultant*
*Dallas*

The Middle East has been estimated to contain approximately 65% of the world's oil.[1-3] Ultimate recoverable "reserves" growth through time has been observed both in the aggregate and for individual oil fields in many parts of the world.

One common average "multiplier factor" for ultimate field recoverable volume as a function of "earliest known reserves estimate" is 7.1.

The 2005 book "Twilight in the Desert," which exposed questionable oil reserves figures in the Middle East, created a great honking and flapping of wings not only among oil companies and economists but also among political leaders and ordinary citizens.

In the June 2, 2007, issue of Oil & Gas Journal, Sadad Al-Husseini and Moujahed Al-Husseini further detailed the huge discrepancies between different analysts' oil reserves calculations for Iraq in particular (whether proved reserves or proved plus geologically probable reserves).[4]

Further discussion of reserves estimates, which can sometimes vary by two orders of magnitude, seems warranted. The following article will discuss distribution patterns of Middle East oil reserves of giant oil fields, geographically, stratigraphically, and with respect to reservoir type.

Historical trends in oil and gas reserves and examples of growth factors for individual field reserves require us to be more optimistic than "Twilight in the Desert" but skeptical about some of the more sensational reserves claimed by IHS Inc. in Iraq, for instance, where insufficient attention was paid to certain geological factors (overmaturity of Silurian source rock and poorer Jurassic reservoir quality than in neighboring Saudi Arabia).

## SUPERGIANT MIDDLE EAST OIL FIELDS*

Table 1

| Top 33 ranked oil fields | Country | Primary reservoir | Recoverable oil, billion bbl |
|---|---|---|---|
| Ghawar | Saudi Arabia | Upper Jurassic carbonates | 90 |
| Burgan | Kuwait | Lower Cretaceous sandstone | 86 |
| Safaniya | Saudi Arabia | Lower Cretaceous sandstone | 32 |
| Majnoon | Iraq | Lower Cretaceous sandstone | 30 |
| Rumaila | Iraq | Cretaceous carbonates, sandstones | 22 |
| Zakum | Abu Dhabi | Lower Cretaceous carbonates | 17 |
| Kirkuk | Iraq | Tertiary, Cretaceous carbonates | 17 |
| Manifa | Saudi Arabia | Lower Cretaceous, Upper Jurassic | 15 |
| Umm Shaif | Abu Dhabi | Lower Cretaceous, Upper Jurassic carbonates | 14 |
| Zuluf | Saudi Arabia | Lower Cretaceous carbonates | 14 |
| Ahwaz | Iran | Tertiary, Cretaceous carbonates | 13 |
| Abqaiq | Saudi Arabia | Upper Jurassic carbonates | 13 |
| Khurais | Saudi Arabia | Upper Jurassic-Paleozoic carbonates/sandstones | 12 |
| Marun | Iran | Tertiary-Upper Jurassic carbonates | 12 |
| Berri | Saudi Arabia | Upper Jurassic-Paleozoic carbonates | 11 |
| Gachsaran | Iran | Tertiary, Upper Cretaceous, Lower Cretaceous | 11 |
| East Baghdad | Iraq | Lower Cretaceous sandstone | 10 |
| North field | Qatar | Permian carbonates-Devonian sandstone | 10? + gas |
| Bu Hasa | Abu Dhabi | Lower Cretaceous carbonates | 9 |
| Kuh-e Mand | Iran | Tertiary-Cretaceous carbonates | 9? |
| Agha Jari | Iran | Tertiary-Cretaceous carbonates | 9 |
| Raudhatain | Kuwait | Upper Cretaceous-Lower Cretaceous | 8 |
| Khafji | Kuwait | Lower Cretaceous sandstone, carbonates | 7 |
| Qatif | Saudi Arabia | Upper Jurassic, Middle Jurassic carbonates | 6 |
| Marjan | Saudi Arabia | Upper Cretaceous, Lower Cretaceous Jurassic carbonates | 6 |
| Bab | Abu Dhabi | Lower Cretaceous carbonates | 6 |
| Fateh | Dubai | Upper Cretaceous carbonates | 6? |
| Sabriya | Kuwait | Upper Cretaceous carbonates, Lower Cretaceous sandstone | 5 |
| Asab | Abu Dhabi | Lower Cretaceous carbonates | 5 |
| Zubair | Iraq | Upper Cretaceous carbonates, Lower Cretaceous sandstone | 5 |
| Shaybah | Saudi Arabia | Lower Cretaceous carbonates | 5 |
| Dukhan | Qatar | Upper Jurassic, Middle Jurassic carbonates | 5 |
| Abu Sa'fah | Saudi Arabia | Upper Jurassic carbonates | 4 |

*Eighty to 90 fields have greater than 1 billion bbl of ultimate recoverable oil.
Source: Christian (from GeoArabia, Vol. 2, No. 3)

## *Introduction*

Plotted on probability paper, about 400 significant Middle East oil fields had a 50 percentile (median) reserve size 10 years ago of 150 million bbl[5] (Fig. 1).

The median reserve sizes for seven other producing basins, also plotted on Fig. 1 for comparison, average about 20 million bbl. Some 40 years ago this 150 million bbl median figure would have been an estimated 250 million bbl, and for Saudi Arabia, Iraq, and Iran separately, median reserve sizes of about 500 million bbl were estimated by the writer at that time. Of course median reserve sizes tend to

decline with time as exploration in any given area reaches a more mature stage.

Presently at least 80 to 90 Middle East oil fields have ultimately recoverable "reserves" greater than 1 billion bbl each. Of these 80 or more giant fields, the top 33 supergiants exceed about 5 billion bbl each (Table 1).

Ghawar, the world's largest oil field, has at least 90 billion bbl recoverable from Upper Jurassic limestone reservoirs. Even without access to Saudi Aramco proprietary data, one can imagine recent stratigraphic trap gas-condensate discoveries on Ghawar's east flank could increase the final total at Ghawar to perhaps 92 billion to 95 billion bbl of oil or barrels of oil equivalent (BOE) on a btu basis.

## Supergiant oil fields

The 33 supergiant oil fields listed on Table 1 are distributed geographically as follows: 11 are in Saudi Arabia, 6 are in the United Arab Emirates, 5 are in Iraq, 5 are in Iran, 4 are in Kuwait, and 2 are in Qatar.

These same supergiant oil fields are distributed according to main reservoir rock as follows: 28% in Lower Cretaceous carbonate, 20% in Tertiary carbonate and clastics, 18% in Lower Cretaceous sandstones, 17% in Upper Jurassic carbonates, 11% in Upper Cretaceous carbonates, and 6% in Paleozoic sandstones and limestones.

Barrels of reserves are distributed in a different way: 32% in Lower Cretaceous sandstones, 31% in Upper Jurassic carbonates, 15% in Lower Cretaceous carbonates, 11% in Tertiary carbonates, 6% in Paleozoic sandstone and carbonates, and 5% in Upper Cretaceous carbonates.

Looked at in different ways, one can note that of the top seven ranked fields, 3 are in Iraq, 2 are in Saudi Arabia, 1 is in Kuwait, and 1 is in Abu Dhabi.

And finally, it can be observed that of the top seven fields, 1 (the largest) produces from Upper Jurassic limestones and dolomites, 3 (including the second largest) produce from Lower Cretaceous sandstones, 2 produce from Cretaceous limestones, and 1 produces from an Oligocene limestone/sandstone reservoir.

Ignored here is the gas supergiant North field, in offshore Qatar, which may have reserves higher than 1 quadrillion cubic feet, and perhaps 10 to 20 billion bbl of condensate.[6 7]

## Reserves trends

In 1988, the late Z.R. Beydoun of Beirut and London published a collection of oil and gas reserves estimates for the entire Middle East. Field by field tabulations of proved published reserves

available at that time totaled 408 billion bbl of oil and 926 tscf of gas.

Saudi Aramco's 1988 annual report assessed remaining proved reserves in Saudi Arabia alone at 252.4 billion bbl and implied total "possible" geological reserves could have been as high as 315 billion bbl of oil and 253 tcf of gas.

Reserves growth since 1988 in proved as well as geologically probable categories (from OGJ, US Geological Survey, and similar sources) have increased enormously.

Up to Jan.1, 2005, or thereabouts, cumulative historical oil production from the Middle East is estimated to have been 320 billion bbl. Remaining proved Middle East oil reserves are reportedly about 700 billion bbl.[8 9]

No attempt to forecast yet to be discovered oil is included here, and for that matter, numerous oil and gas "discoveries" of small or undetermined size scattered throughout the Middle East are not included. More than a dozen such unevaluated or subcommercial discoveries (mostly gas) are known to exist in Syria alone.[10]

Worldwide oil discoveries (especially of giant sized oil fields) reached an annual peak no later than 1962. That year an inflection point in the rate of change in the growth of world oil reserves (ultimate recovery) took place, and annual reserves additions have been declining ever since.

Worldwide annual oil production, on the other hand, has continued to increase for at least 40 years (minor exceptions being caused by economic recessions, oil embargoes, or wars).

If two Gaussian or near-Gaussian curves are constructed which plot (a) annual additions to oil reserves, and (b) annual oil production worldwide (the King Hubbert-L.F. Ivanhoe approach), the two curves cross in 1979 or 1980, and so net remaining worldwide oil reserves have been declining steadily since 1980.[9]

Integrating the areas under the two curves, it is evident that eventually the two areas must be equal: that is, total ultimate production obviously cannot exceed total discovered reserves; and since there has already been a 42-year period of producing history since the peak discovery year and a 25-year period of producing history under conditions of declining net remaining reserves worldwide, reasonable mathematical projections are able to suggest more or less permanent producibility shortfalls beginning about the year 2010, or perhaps 2020.

After that an inevitable world decline in oil production has been forecast. Of course this does not take into account the mining of large tar sands deposits in Venezuela and Canada or oil use con-

versions to gas use, both of which are already beginning to take place.

Within a decade or so natural gas use on a BTU basis may rival or exceed crude oil use worldwide.[11]

## Growth in single fields

The growth through time of oil and gas reserves in single fields deserves to be considered separately.

The most dramatic example at hand is supergiant North field ("North Dome"), off Qatar.[5] Fig. 2 indicates more or less "official" (published) gas reserves (excluding condensate) increasing hugely from early times at or soon after discovery to perhaps more than 1 quadrillion cu ft now. It is estimated that 10 to 20 billion bbl of condensate are potentially recoverable also. This could be considered an extreme case in historical reserves growth.

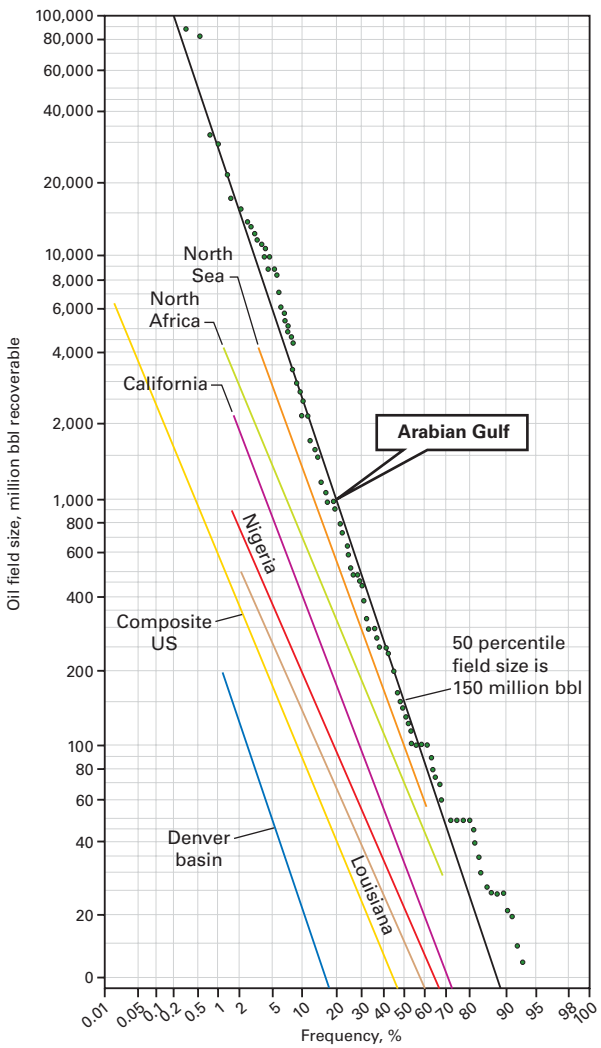
Yet a former Mobil Oil petroleum engineer, Chet Doyle, in an unpublished study in the western states of the US more than 40 years ago, documented the increases in reserves estimates for a considerable number of oil fields in California basins, as also shown here graphically on Fig. 2. Averaging his results for the group of fields results in a 7.1 multiplier factor which had to be applied to the earliest calculated reserves in order to arrive at ultimate recoverable reserves calculations at or near full field development and decline. Less radical multiplier factors are cited by Verma et al.[3] On the other hand, multipliers as high as 9 or 10 are claimed by Attanasi et al.[12]

Reasons for such a large ratio (a 7.1 multiplier, or thereabouts) may be assumed to be partly technological (more wells, more information, better knowledge of the reservoir, better control of geological or geophysical mapping), and partly a matter of economic or political conditions or policy.

In the latter categories can be included the timidity or conservatism of economists, planners, and bankers poten-

**SIZE DISTRIBUTION OF 400 MIDDLE EAST OIL FIELDS***

Fig. 1




*The chart shows seven other world basins for comparison.
Source: Christian, GeoArabia, Vol. 2, No. 3, 1997.

tially involved in underwriting development schemes (as opposed to sometimes overly exuberant exploration geologists and geophysicists intent on drilling and developing favorite prospects).

National and international income tax, royalty, and depreciation terms, and even Wall Street attitudes or oil company bonus policies may also create conscious or subconscious motives on the part of oil company management (and host government authorities) to either inflate or minimize early geological reserves estimates.

The sudden doubling of stated reserves by countries at war, or at times when World Bank loan applications are pending (or for reasons of national pride), may also be mentioned.

Hussain[13] ascribes the huge increases in stated oil reserves by gulf members of OPEC in about 1985 to the fact that OPEC production quotas were at the time determined in part by individual country oil reserves.

Similar circumstances of inflated reserves statements by the former Superior Oil Co. led Mobil Oil Corp. to outbid competitors in a hurried buyout ordered by top management without adequate auditing of Superior's stated reserves.[14] Superior's top executives had been receiving annual bonuses based on additions to reserves.

Most recently, Sadad and Moujahed Al-Husseini[4] have highlighted enormous discrepancies (by two orders of magnitude) in so-called "proved" and "potential" oil reserves for Iraq in particular by different analysts.

## Precision in terms

The kinds of discrepancies in reserve estimates mentioned here are most severe when there is a failure to discriminate between "proved" reserves and "probable or possible" reserves.

Proved reserves are those that have been blessed by engineers, planners, bankers, and historians, for instance following complete infill drilling and production to a point approaching the time of field abandonment, while "geologically probable or possible" reserves are calculated much earlier on the basis of a single discovery well (or two or three) plus the planimetered area of a seismically mapped structural trap.

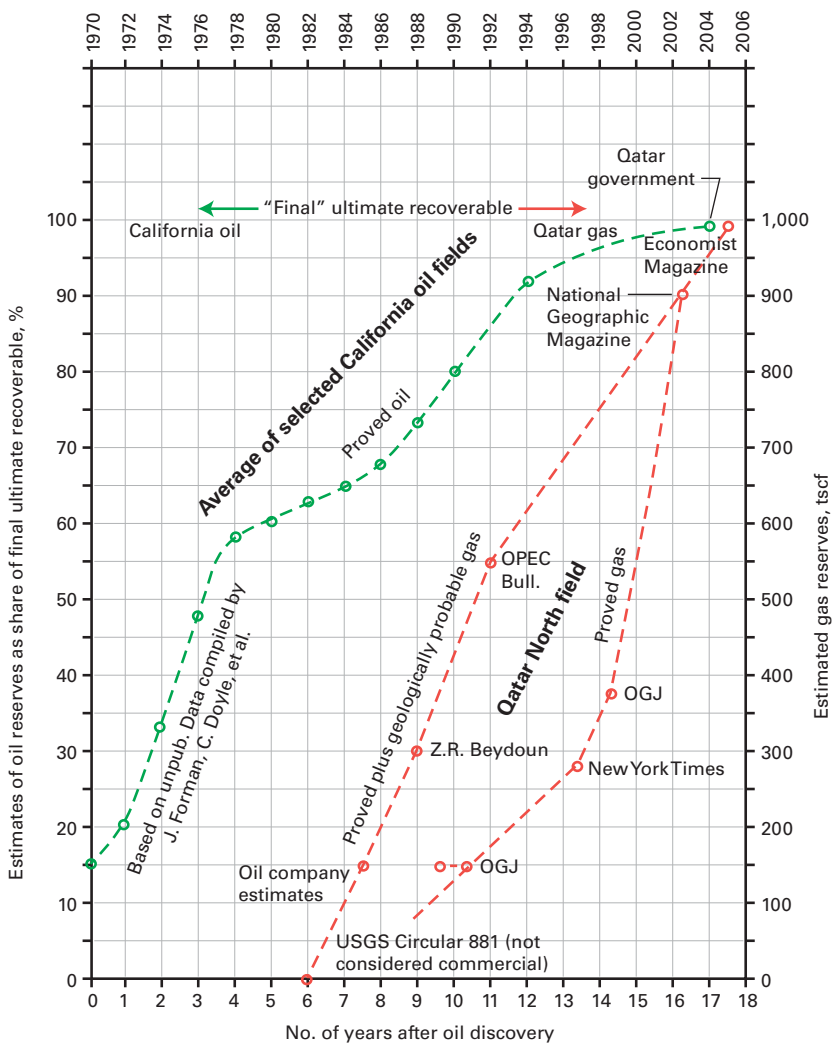
The trouble with such big differences in calculated or estimated reserves is that economic decisions (to develop, to build a pipeline, to abandon) cannot rationally be reached taking into account either extreme, but rather require economic evaluation of risk factors of various kinds as well as the extremes between early "reserve" estimates by engineering and economic managers on one hand vs. the early estimates of explorationists on the other hand.

The legendary petroleum engineer John Arps pointed out during a 1967 AAPG Lecture Tour that "management's interest in estimates is maximal when information is minimal and vice-versa," making for lots of arguments between optimistical geologists and pessimistical engineers![15]

The need for management decisions to look at both sides of such disagreements at an early stage and to introduce probability and risk analysis into the decision equation is obvious. The significance of early understatement of proved and potential oil reserves was

### HOW RESERVE ESTIMATES HAVE GROWN FOR SELECTED FIELDS

Fig. 2



clearly appreciated by the Saudi Petroleum Mininster, Ali Al-Naimi, in an address to the World Affairs Council in Dallas in May 2004.

## Acknowledgments

The writer thanks GeoArabia's editor-in-chief Moujahed Al-Husseini, Jeorg Mattner, and the graphics and production staff of Gulf PetroLink for their past assistance from time to time in the preparation of this article. The late John Forman provided data relating to California reserves used in Fig. 2. ✦

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**The author**

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# EXPLORATION & DEVELOPMENT

## Argentina

Two wells on the Medianera block in the Neuquen basin intersected an oil column in the Cretaceous Quintuco formation, identifying a new field with large but unspecified areal extent, said Antrim Energy Inc., Calgary.

The M3001 and M3002 wells were drilled to 1,400 m. M3001 swab-tested 93 b/d of oil and 30 b/d of water from 12 m of net pay in Upper Quintuco. The well also flowed at rates as high as 3 MMcfd from Lower Quintuco under high pressure.

Antrim has 84 sq km of 3D seismic data that indicate the discovery's lateral extent and is working to isolate the water zone. The company placed the oil zone on production and plans to test the M3002 well shortly.

Antrim holds 70% working interest in the block and plans to delineate the discovery and also bid for the adjacent Tres Nidos Sur license.

## Madagascar

OMNIS awarded exploration license 34/07/TM in the Mozambique Channel west of the Morondava basin to EnerMad Corp., an affiliate of Pan African Mining Corp., Vancouver, BC.

The license covers 16,845 sq km and is subject to a profit sharing contract. EnerMad has identified targets at 3,500 m in 1,300 m of water.

EnerMad, managed by experienced Calgary personnel, said it has more than $2 million in cash and may go public this fall.

## Morocco

Sphere Petroleum QSC, Doha, Qatar, plans to take a farmout in exchange for an option to earn 50% interest from TransAtlantic Petroleum Corp., Calgary, in the 222,000-acre Tselfat exploration permit onshore in northern Morocco.

Sphere, with Australian ownership and the first 100% foreign owned company in Qatar, will fund a 110 sq km 3D seismic survey over abandoned Haricha field and the northern part of idle Bou Draa field in early 2008 and further geological studies to a maximum of $4.5 million (US).

If it exercises the option, Sphere will fund the drilling and testing of an exploratory well to 6,500 ft on a subthrust prospect and replace the company's bank guarantee deposited with the Moroccan government.

TransAtlantic will remain operator of the permit through the exploration phase, which extends to May 2009. The permit contains Haricha, Tselfat, and Bou Draa fields discovered in or before the 1950s. The 3D survey and studies support possible redevelopment of Haricha and probe deeper prospectivity on the permit.

Provided that Sphere exercises the option, interests are TransAtlantic and Sphere 37.5% each, and Morocco's Onhym is carried for 25% of costs in the exploration phase.

## Uganda

Exploration may be nearing on Block 5 north of Lake Albert in northwestern Uganda near the border with Sudan.

Orca Exploration Group Inc., Road Town, Tortola, British Virgin Islands, took an option from Neptune Petroleum (Uganda) Ltd., a subsidiary of Tower Resources PLC, to earn a 50% interest in the 6,040 sq km license.

Tower plans to shoot 250-300 line-km of 2D seismic starting in November 2007 on the block (see map, OGJ, Sept. 4, 2006, p. 56).

Orca will fund 83.33% of the 2007 seismic program and certain past costs to a maximum $6 million carried cost. After data interpretation it will have the exclusive right to acquire a 50% working interest in Block 5 in return for funding 83.33% of two exploration wells to a maximum $10-15 million depending on whether the wells are tested.

## Venezuela

The PetroCumarebo joint venture started gas production from La Vela field in the East Falcon Block at 10 MMcfd into Petroleos de Venezuela's Interconnection Centro Occidente pipeline to the Paraguana peninsula refinery complex.

PetroFalcon Corp., Carpenteria, Calif., which owns 40% of PetroCumarebo, said the joint venture still has 12 MMcfd and 150 b/d of oil shut-in at Cumarebo field due to the ICO pipeline closure on Dec. 6, 2006. Management has been advised that these deliveries will resume in the fourth quarter of 2007.

## Arkansas

PetroQuest Energy Inc., Lafayette, La., acquired several parcels of leases in the Fayetteville shale trend in the Arkoma basin, bringing its position to more than 17,000 net acres.

Most of the land is in Van Buren County, and more purchases are planned this year. PetroQuest plans to participate in the drilling of several nonoperated horizontal wells in the next few months.

The company also said it began operating a second rig in the Woodford shale in the basin in Oklahoma, where it has decided to explore alternatives for its 180 miles of gathering systems that haul 30 MMcfd of gas.

## Utah

Royalite Petroleum Co. Inc., Austin, received a federal permit to drill an 8,500 ft wildcat to Lower Jurassic Navajo sandstone on the Central Utah Hingeline, where it holds more than 67,000 net acres.

Location for the Royalite Federal 27-1 is in 27-27s-3w, Piute County, 2 miles east of Marysvale, 26 miles south-southwest of Covenant oil and gas field, the Hingeline's only discovery to date. The state drilling permit is also in hand.

The company, which has 100% working interest and 87.5% net revenue interest in the prospect, is pursuing numerous acquisitions in the 150-200 mile long trend.

# Lasers used to clad, strengthen nonmagnetic steel equipment

**Nina M. Rach**
Drilling Editor


New hard facing materials and corrosion-resistant alloys broaden the market for laser cladding services. Laser cladding, a type of laser surface alloying, is a process that precisely applies a uniform surface coating to tools and equipment, and provides protection against corrosion and wear without inducing magnetization.

The laser process involves fusing an alloy layer to a substrate with minimum melting of the substrate. The aim is to overlay and solidly bond one metal with another.[1]

Oil field tools are routinely subject to abrasion and corrosion, degrading their surface integrity both mechanically and chemically. The industry's tools have become increasingly sophisticated, as engineers incorporate exotic base materials, and wear protection is ever more important to safeguard capital investments and keep projects on schedule.

Cladding is a less-expensive alternative to manufacturing tools, structural parts, and downhole components from solid corrosion-resistant or wear-resistant alloys. Applying a surface coating (hard facing) improves wear and corrosion resistance, results in longer component life, and keeps equipment in service longer. Cladding can be used to create an entirely new surface or it can repair and renew damaged or worn surfaces.

Laser cladding is particularly useful for protecting stabilizers and other drillstring components made of nonmagnetic steel. Laser-applied, tungsten carbide composites can provide the same protection against abrasion as carbide inserts, according to one supplier.[2]

## Nonlaser approaches

Traditionally, hard facing was applied manually (stick-weld overlays) but this process is time-consuming and subject to non-uniformity or irregularities in surface cover. It also requires application of multiple layers, causing a thicker surface buildup. Furthermore, heating the base metal causes surface contaminants to seep into the weld pool, and electricity and heat induce magnetization in the object being clad.

Welding is cost-effective, however, for objects that are not required to be nonmagnetic, such as drillbits and bit shanks.

According to Mark Juckett, hardband product line manager at NOV Tuboscope's global drill pipe services, MIG (metal inert gas) welding is the industry standard for applying hard facing (hardbanding) to drill pipe. The process can be automated, but requires an experienced welder to operate.


Oven sintering is another method of applying hard facing, but often repairs are not possible and the process is costly and time-consuming.

The hexavalent hard chrome plating method is also falling from favor due to the slowness of the coating process,

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*This $CO_2$ laser is melting the matrix of tungsten carbide powder cladding material and fusing it to an oil field grade stainless steel tubular (Fig. 1; photo by Laser Cladding Services Ltd.).*

need for multiple layers, lack of coating uniformity, and health and environmental concerns.[3]

A relatively newer, thermal spray application method, high velocity oxy-fuel (HVOF), has been used in the oil patch since 1995 to replace chrome plating, on items such as ball valves, hydraulic cylinder rods, mandrels, and risers and tensioner rods for offshore rigs.[3]

## Components

Laser cladding is very complex, involving many processing parameters, such as power-beam spot size, feed rate, and powder flow. The process requires a high-powered laser, and sophisticated control and delivery systems (Fig. 1).

Many types of lasers are used, including $CO_2$, Nd:YAG (yttrium aluminum garnet), diode, and fiber lasers. $CO_2$ lasers are the most commonly used in laser cladding but the Nd:YAG laser's wavelength is more appropriate for metal processing[1] and a diode-laser cladding system can clad with half as much power as a $CO_2$ laser.[4] Sweden's Duroc Engineering recently developed a portable, 4-kw fiber laser system that can be transported by helicopter offshore.[5]

Technogenia, based in Saint-Jorioz, France, began using a 5-kw $CO_2$ laser for cladding in 1993, according to Herve Maybon, chief executive officer. The company began research on diode lasers in 2000 under European Craft Project No. 1, and installed new diode lasers in its plants in Sheffield, England, in 2003, Saint-Jorioz in 2005, and in Conroe, Tex., in 2007. [Technogenia diode laser pictured on front cover of this issue.]

Gremada Industries Inc., based in Fargo, ND, began offering laser cladding in 1994, according to Paul Phelan, sales engineer for Laser Cladding Services (LCS) Ltd. In 2001, Gremada opened LCS in Houston; the company runs both $CO_2$ and more efficient diode lasers.

Newer lasers can incorporate robotic arms to maneuver complicated geometries.

Control systems are fundamental to laser cladding operations, often using multiaxis computer-numeric control (CNC) systems. A CNC system can be programmed to follow complex geometries, Phelan says.

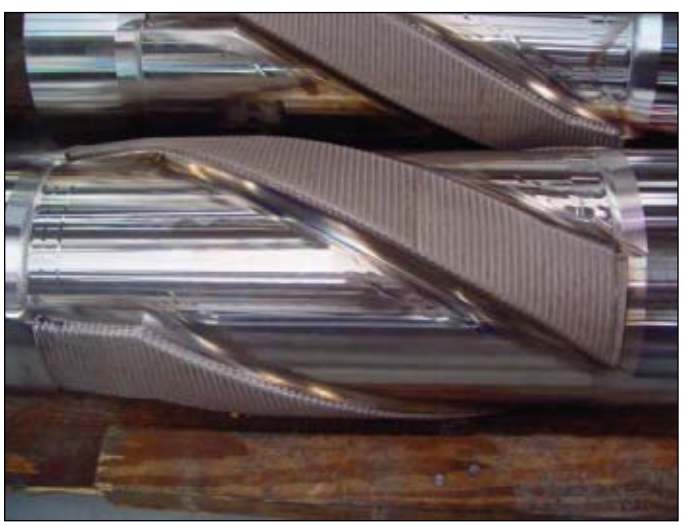
Different material delivery systems can utilize powder (most common), wire, or fiber.

## Materials

Commonly clad substrate materials include carbon steel, carbide composites, cobalt or nickel base super alloys, stainless steel, and titanium alloys. Oil field components are built using all of these and more.

Cobalt or nickel-based super alloys are often used in manufacturing and resurfacing of LWD (logging while drilling) and MWD (measurement while drilling) tools such as rotors, stators, impellors, drilling centralizers, erosion inserts, fishing heads, and landing, wear, and turbine sleeves (Fig. 2). These alloys are also used in mud-motor bearings, hydraulic cylinder rods, filter screens, kelly valve trim, cages, sucker rod couplings, annular blowout preventers, and subsurface safety valves (flappers, darts).

Many different hard-facing materials can be applied with laser cladding, but tungsten carbides are the



*The laser cladding process is used to apply tungsten carbide hard facing to drilling stabilizers (Fig. 2; photo by Laser Cladding Services Ltd.).*

most often used. It forms hard, tough coatings; carbides resist abrasion due to their hardness. Pure cast tungsten carbide spheres, which vary in size, form the wear component in a nickel-alloy matrix that is either formed into continuous, flexible welding rods (Fig. 3) or a powder for laser cladding. These spherical tungsten carbide mixtures are produced by a number of different companies, including spherotene from Technogenia.

Among the companies that provide materials for engineered surface coatings used in laser cladding are:

- Carpenter Powder Products, part of Carpenter Technology Inc., Bridgeville and Reading, Pa., and Torshälla, Sweden.
- Durum Verschleiss-Schutz GMBH, Willich, Germany.
- Stellite Coatings, part of Deloro Stellite Group, Goshen, Ind.

More complex alloys are used for surface enhancements, corrosion, and oxidation.

For instance, exposed portions of subsea riser supports made of commercial pipe with welded hanger flanges are laser clad with nickel-based alloys to add corrosion resistance to seawater.

*Using an oxyacetylene torch, a welder applies a tungsten carbide-nickel alloy hard facing material in the form of a continuous, flexible rod or "rope" (Fig. 3; photo from Technogenia).*

## Process

Laser cladding for the oil field is usually a single-stage application process that involves either pre-placing or blowing powdered cladding material on the substrate (object to be clad). The laser generates a molten pool in the presence of an inert gas. To cover a large surface, the laser must follow overlapping tracks. The resulting surface layer is usually 1-2 mm thick.[6]

Technogenia developed its Lasercarb process with the assistance of Irepa Laser in Strasbourg and the CALFETMAT research laboratory in Lyon. The process uses a computer-numeric control system to regulate temperature and power.

Although laser cladding imposes stresses on the material by the high local heat generated by the laser and the length of time required to complete multiple, overlapping passes across large surface areas, the heat input is still much lower than traditional weld overlay processes.

A two-stage laser cladding process exists that is limited to flat surfaces and is more prevalent in other industries.

## Innovations

At the laser applications division of the Fraunhofer USA Center for Coatings and Laser Applications in Plymouth, Mich., researchers partner with Michigan State University on a variety of projects. Among the innovations was a laser-cladding method that uses a 3-kw diode laser and a coaxial powder-feeding nozzle to apply tungsten carbide.[7] The diode process is one-third the cost of $CO_2$ laser application and is successfully being used for downhole drilling equipment.

Laser-cladding research is also underway at the University of Waterloo, Ont.

Ehsan Toyserkani, in the university's "mechatronics" engineering group, is working on measuring clad geometry microstructure in real-time, an essential control signal for a closed-loop control of laser cladding.

Toyserkani, Amir Khajepour, and Stephen Corbin, authors of a recent book on laser cladding,[6] were awarded a patent in 2006 outlining a system and method for intelligent closed-loop control of laser cladding by powder injection.[8]

The researchers focused on improving the wear resistance of high-temperature turbine blades, but the methods are applicable to most oil field requirements.

Researchers in China are working on aluminum oxide (Al2O3) coatings on AZ91D magnesium alloy and 7075 aluminum alloy.[9,10]

Surface laser cladding with a $CO_2$ laser was recently used to develop iron-based powder coatings containing nano-$Al_2O_3$ particles. Researchers found that adding nano-$Al_2O_3$ particles significantly improved mechanical properties, particularly wear resistance.[11]

Corrosion resistance is also a subject of current research, although in general practice, it's common to use commercially available corrosion-resistant alloys in laser cladding. Russian researchers found that adding nickel to chromium cladding on stainless steel considerably enhanced pitting and corrosion resis-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tance compared with surfaces clad with chromium alone.[12]

Other process innovations include:

- Advances in powder metallurgy and powder delivery systems.
- Using preheated wire instead of powder to increase speed and efficiency, reducing dust and waste.
- Incorporating an external energy source to preheat the substrate (induction heating).
- Technologies and automation to clad large surfaces efficiently.

*The carbide inserts of this 8-in. OD drillbit were clad with a dissimilar metal to protect the wear surfaces and extend service life (Fig. 4, photo from Laser Cladding Services Ltd.).*

## Market, industry

Even operators such as ExxonMobil have worked on laser cladding, as shown in a review of US-issued patents. But laser cladding wasn't widely commercialized until the mid-late 1990s.

Now, engineers at operating companies generally specify drilling requirements and service companies provide the specified equipment and services. Equipment manufacturers employ machine shops to build tools and arrange for specialty services such as laser cladding of certain components.

Laser cladding facilities are generally found in areas with heavy oil field demand, such as Texas and Alberta, as well in unexpected spots, such as the foothills of the French Alps, from which products are shipped worldwide.

According to Holger Stibbe, director of MWD/LWD development, Baker Hughes INTEQ uses a variety of proprietary wear resistant coatings and several laser cladding vendors. Different patterns are applied to improve wear resistance of MWD and LWD tools. Stibbe told OGJ that the availability of laser cladding services has improved in the last few years, with vendors in the US, France, and UK serving market needs. Baker uses predominantly $CO_2$ lasers and some diode lasers.

At the Offshore Technology Conference this past May, Houston's Laser Cladding Services discussed its partnership with NASA to develop specialized laser cladding for a control valve on a rocket engine test stand in NASA's rocket engine testing program at the Stennis Space Center in Mississippi.[13]

Phelan told OGJ that the majority of the company's work is for the oil industry, and the laser process is used for choke and kill lines, downhole tools, ball bounce, hydraulic cylinder rods—even the occasional drillbit (Fig. 4).

Laser cladding is useful wherever components need to be protected from abrasion, cavitation, fretting, particle erosion, and corrosion. Many of the world's largest oil field equipment designers and manufacturers—including Baker Hughes INTEQ, Halliburton, NOV Tuboscope, Schlumberger, and Smith International—use some level of laser cladding. ✦

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Composite drillable tools available from Baker Oil Tools include a liner wiper plug (top left), pack-off insert (top right) and composite bridge plug (above; Fig. 1).


# Hot-wet downhole conditions affect composite selection

**Yusheng Yuan**
**Jim Goodson**
*Baker Oil Tools*
*Houston*


Advanced fiber-reinforced polymer composites offer new options for working on and completing deep wells that have high temperatures and pressures (HT-HP) and produce corrosive fluids, although proper material selection requires an understanding of the composite's hot-wet thermomechanical behavior.

Companies can include composites in drilling, logging, completion, production, and workover. Completions and workovers often require tools set temporarily in a wellbore that need to be made from easily drilled or milled out materials. Offshore deepwater extended-reach drilling and completions require materials for downhole tubular components and equipment that are lightweight and fatigue-resistant.[1,2]

Advanced fiber reinforced, high-temperature polymer composites can function at elevated temperatures in deep wells while offering advantages such as lightweight, corrosion resistance, long fatigue life, and easy removal. Furthermore, nonconductive and nonmagnetic high-temperature polymer composites are ideal for resistivity and induction logging tools.[2]

Aerospace and other industrial applications, including oil field operations, have incorporated in various applications such high-temperature polymers as polyimides, cyanate esters, phenolics, high-temperature epoxies, thermoplastics, and their composites.[1,2]

Under moisture or a wet condition with high-temperature, however, most polymers and their composites behave differently from their original dry state because of severe hydrolytic and hydrothermal degradations from the high-temperature wet environment.[3]

It is therefore important to understand the HT-HP hot-wet thermomechanical behavior of various high-temperature polymer resins, reinforcement fibers, and their composites.[3]

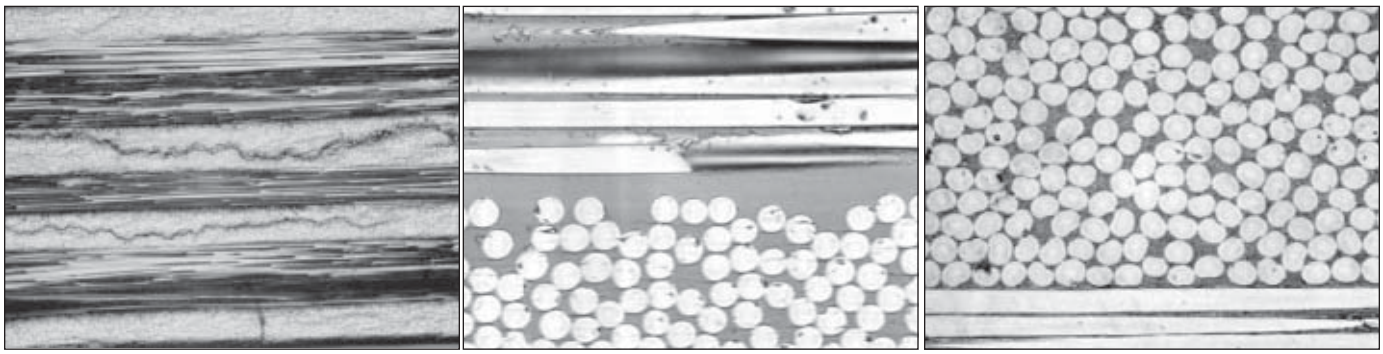
## Composites downhole

The petroleum industry has actively researched and used composites downhole since the mid-1960s. It has developed numerous fiber-reinforced composite products for downhole operations, such as sucker rods, tubing and casing, drill pipes, coiled tubing, and well screens.[1,2] These applications, however, have limited temperature ratings, mostly below 200° F., and lack long-term performance reliability under HT-HP downhole conditions.

Many downhole operations require service tools that perform in a hot-wet fluid at temperatures greater than 400° F. and pressures greater than 10,000 psi. These conditions require more advanced HT-HP hot-wet resistant composite materials.

## Sucker rods

Development of fiberglass sucker rod strings for beam-pumped oil wells



*The micrograph (×50) on the left shows a polished cross-section of an EP-2/AS4 sample after exposure in 3% NaCl brine at 400° F., 5,000 psi for 96 hr (Fig. 2a). The middle micrograph (×1,000) is of a polished cross-section of an EP-1/T300 sample after exposure in 3% NaCl brine at 400° F., 5,000 psi for 96 hr (Fig. 2b). On the right, is a micrograph (×1,000) of a polished cross-section of a PH-2/T300 sample after exposure in 3% NaCl brine at 400° F., 5,000 psi for 72 hr (Fig. 2c).*

started in the mid-1970s to meet the demand for downhole corrosion resistance.

These strings had pultruded fiberglass rods with steel connectors at two ends. Pultruded fiberglass rods possess high tensile strength, are lightweight, and have good corrosion resistance.

With proper string design, the fiberglass sucker rods can increase the production rate, reduce energy consumption, and provide longer rod life.

Temperature remains the major limitation for expanding field applications. Most operators install the rods in wells with bottomhole temperatures of less than 180° F.

## Tubulars

In the early 1980s, the industry started using $CO_2$ flooding for enhancing oil recovery. Mixing $CO_2$ and water causes severe corrosion to traditional steel tubing strings.

These corrosion problems expanded the use of corrosion resistance and lightweight, glass fiber-reinforced polymer (GRP) pipe to high-pressure downhole and surface applications, including water and gas injection lines, and downhole tubing and casing.

To establish an industrial standard, the American Petroleum Institute (API), in the mid 1980s, initiated the development of pressure-rating methodologies and purchase specification for commercial high-pressure fiberglass line pipe (API 15HR) and downhole tubing (API 15TR).

API, in 1992, only published API 15HR. This specification provides purchase guidelines and pressure-rating methods for high-pressure fiberglass line pipes with internal pressure rating from 500 to 5,000 psi, but the service temperature specified for long-term applications was limited to less than 150° F.

Although several manufacturers sell filament-wound GRP downhole tubing and casing products, no industrial standards or specifications exist today for these products.

The primary industry concerns in using these products are the lack of standards and application data and long-term performance uncertainty.

## Composite drill pipe

Horizontal and extended-reach drilling has expanded since the 1980s in both onshore and offshore operations. The heavy weight of conventional steel drill pipe, however, has limited drilling operations.

Lightweight composite materials can reduce the frictional drag of drill pipe on the wellbore. Also carbon fiber-reinforced composite tubular structures are applicable for extended reach and deepwater drilling because of their high torsional stiffness and strength, flexibility, and long fatigue life.

One vendor introduced small-sized flexible composite drill pipe products into the market in the mid-1990s. A major application of this drill pipe is in short-radius lateral drilling.

A program was initiated in 1999 for developing cost-effective, larger sized composite drill pipe for extended-reach and deepwater (ER-DW) drilling. The goal was to attain about a 50% weight saving over steel drill pipe. This would enable ER-DW drilling and real-time data and power transmissions through the drilling string.

Recently, a program developed 6-in. ER-DW composite drill pipe that is now under field evaluation. Because the major reinforcement material in the drill pipe is carbon fiber, and drill pipe is a short-term application, the pipe usually has a temperature rating higher than other downhole fiberglass products.

Drillers, however, commonly use composite drill pipe in holes that have a temperature of less than 250° F.

## Spoolable tubing

Although the industry widely uses metallic spoolable tubing in downhole applications, limitations such as heavy weight, low corrosion resistance, short fatigue life, and high thermal conductivity of conventional carbon steel products, have led companies since 1988 to seek new materials for the tubing.

Companies in recent years have made much progress in developing spoolable composite tubular.

The manufacturing of spoolable thermoset composite tubing uses a continuous filament winding process. The


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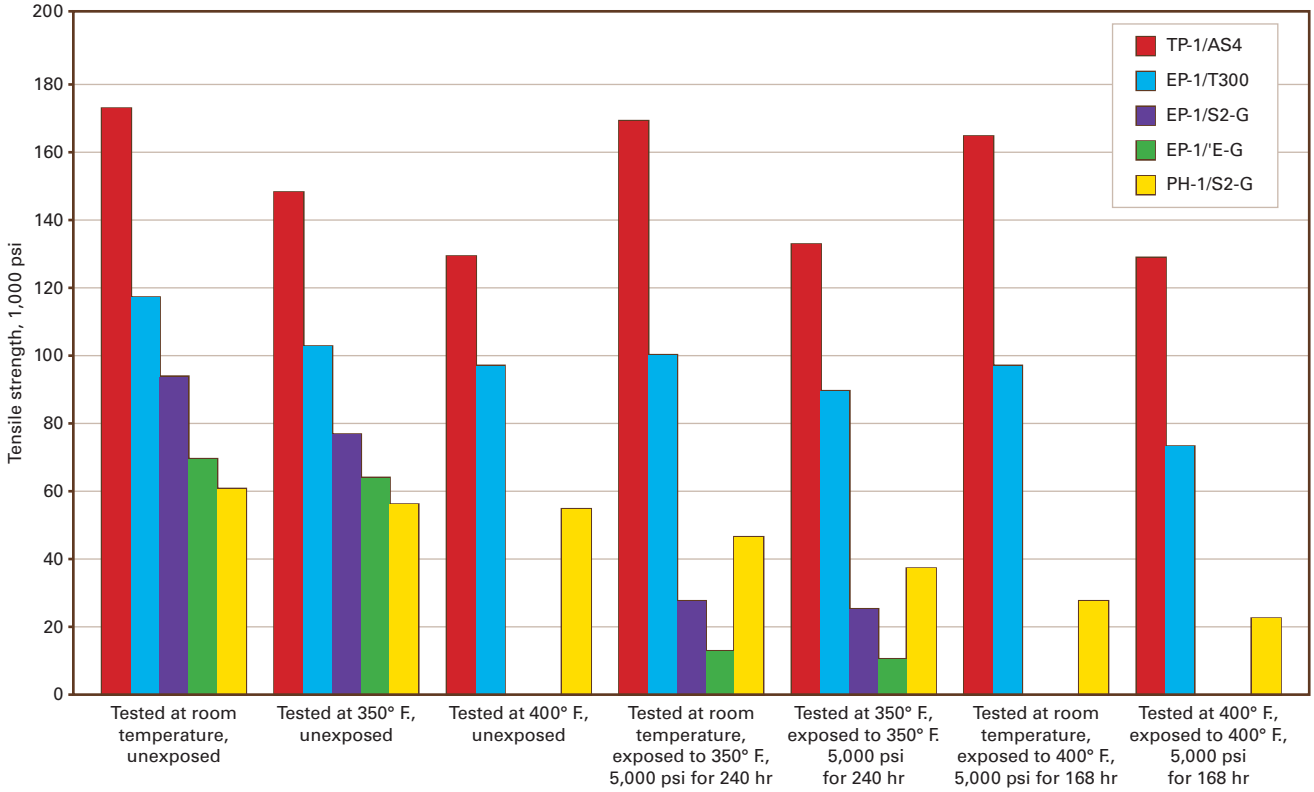
Fig. 3




tubing has an extruded thermoplastic liner, a major composite structural laminate body, and a protective outer layer. During the winding process, the manufacturer can embed in the tubing wall data and power transmission conductors.

Spoolable composite applications include flowlines and injection lines for transporting oil field corrosive fluids and gases, coiled tubing for well intervention, and production tubing in corrosive wells.

Commercialization of composite spoolable tubing products has focused on flowline and injection line applications because major downhole applications such as coiled tubing, production tubing, and "smart" pipe remain under development and evaluation.

Developers still must overcome the low axial stiffness and strength and ensure long-term exposure reliability of composites in HT-HP downhole conditions.

### Logging tools

Resistivity or induction logging tools require a nonconductive and nonmagnetic cylindrical housing structure to contain the electrical and electromagnetic devices and provide mechanical strength, pressure integrity, and resistance to the corrosive downhole conditions.

The materials in the housing structures require certain dielectric properties and electromagnetic radiation transparency.

Advanced glass fiber-reinforced polymer composites are ideal for these applications.

Because the logging process in each run is basically a short-term application under a hydrostatic pressure, the temperature and pressure rating of the logging tools with glass fiber-reinforced epoxy composite may reach 350° F. and 15,000 psi. In deeper wells, the logging tools may have to endure temperatures and pressures greater than 400° F. and 20,000 psi. In these circumstances, the industry will need more advanced HT-HP hot-wet resistant composites.

### Drillable downhole tools

Drilling, completion, and workover operations require various downhole tools, such as packers, bridge plugs, and some cementing tools that are set temporarily in the wellbore and that are removed by drilling or milling operations.

A workover rig usually is needed for drilling or milling out a conventional cast-iron packer or bridge plug and often the work is unwieldy. Multiple bridge plugs set in a multizone wellbore for a remedial job often are time consuming and expensive to remove because of multiple drillstring trips and the need for expensive kill-weight drilling fluids.

Advanced composite materials and structures, incorporated with high-strength fibers and high-temperature resin matrices can be an alternative to cast-iron tools. The composites can

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be engineered to have high mechanical strength and the ability to survive temperatures greater than 400° F. for a period of time.

These advanced composite structures would replace the metal components in various drillable tools and allow easy removal.

Investigations in the design of drillable packer and plug products with nonmetallic components began in the early 1990s, and companies began introducing into the market the composite bridge plug, squeeze packer, or cementing retainer products in 1994.

Other composite drillable products include composite packoff inserts, composite landing collars, and wiper plug systems. Fig. 1 shows some composite drillable products.

Composite bridge-plug applications are usually short-term with a typical 3-10 day duration. The basic version has a 250° F. and 5,000-psi rating; the intermediate version has a 350° F. and 7,500-psi rating; and the HT-HP version has a 425° F. and 12,500- psi rating.

The material design in the basic and intermediate versions was less of a problem than for the HT-HP version. Development of the HT-HP version had to overcome hygrothermal degradation of the materials in the HT-HP hot-wet downhole conditions.

Hygrothermal refers to the change in material properties due to moisture absorption and temperature change.

The following sections discuss the effects of HT-HP downhole conditions on thermomechanical properties of selected high-temperature polymer composites.

## SELECTED HIGH-TEMPERATURE COMPOSITES

Table 1

| Material system | Resin matrix | Reinforcement | Processing method | $V_f$, % |
|---|---|---|---|---|
| EP-1/E-G | Tetra-functional epoxy | E-glass fabric 7781 | Wet lamination | 57 |
| EP-1/S2-G | Tetra-functional epoxy | S2-glass fabric 6781 | Wet lamination | 57 |
| EP-1/T300 | Tetra-functional epoxy | Carbon fabric 3k PW | Wet lamination | 58 |
| EP-2/AS4 | Tetra-functional epoxy | Carbon UD 3k [0/90]sn | Prepreg* lamination | 60 |
| PH-1/S2-G | Commercial resole phenolic | S2-glass fabric 6781 | Prepreg lamination | 59 |
| HP-2/T300 | Developmental phenolic | Carbon fabric 3k PW | Prepreg lamination | 54 |
| TP-1/AS4 | TP aromatic polyetherketone | Carbon UD 3k [0/90]sn | Prepreg lamination | 62 |

*Prepreg—epoxy preimpregnated into the fibers.

### Test program

The test program on the thermomechanical behavior of high-temperature polymer composites under HT-HP hot-wet conditions included as resin matrices two aromatic amine-cured tetra-functional epoxy resins EP-1 and EP-2, two phenolic resins, PH-1 and PH-2, and one thermoplastic aromatic polyetherketone resin, TP-1. Carbon fibers, E-glass, and S2-glass incorporated with these resins formed the composite laminates (Table 1).

The tests excluded polyimide and cyanate ester resins because imide ring, amide group, and ester linkages in these resin families are susceptible to hydrolytic scission in a high-temperature hot-wet environment.

The HT-HP exposure tests were conducted in 3% NaCl brine in a high-pressure autoclave at a temperature between 250° and 450° F. and under a nitrogen pressure ranging from 5,000 to 10,000 psi for 3 to 10 days.

The test program involved the following experimental procedures:

- Water absorption and substance leaching, measured from the composite samples after the environmental exposure.
- Glass transition temperature ($T_g$) of the composites, determined by dynamic mechanical analysis (DMA) from the composite samples before and after the environmental exposure.
- Tensile and compression tests at ambient and elevated temperatures,

## CHANGES AFTER HT-HP EXPOSURE

Table 2

| Material system | Exposure condition in 3% NaCl brine | Net weight gain, % | Water absorption, % | Leaching, % | Thickness change, % | Microstructure examination |
|---|---|---|---|---|---|---|
| EP-1/ E | Room T&P* for 240 hr | 0.14 | | | 0.27 | |
| | 250° F., 50 psi for 240 hr | 1.15 | | | 1.37 | |
| | 250° F., 5,000 psi for 240 hr | 1.15 | | | 1.54 | |
| | 350° F., 5,000 psi for 240 hr | 2.40 | | | 6.24 | Interface debonding |
| EP-1/ S2 | Room T&P for 240 hr | 0.11 | | | 0.14 | |
| | 250° F., 50 psi for 240 hr | 1.19 | | | 1.23 | |
| | 250° F., 5,000 psi for 240 hr | 1.28 | | | 1.23 | |
| | 350° F., 5,000 psi for 240 hr | 1.94 | | | 4.34 | Interface debonding |
| EP-1/T300 | 250° F., 5,000 psi for 240 hr | 1.21 | | | 0.74 | Minor interface debonding |
| | 350° F., 5,000 psi for 240 hr | 1.47 | | | 1.63 | Interface debonding |
| | Room T&P for 72 hr | 0.14 | 0.14 | Undetected | 0.42 | |
| | 250° F., 5,000 psi for 72 hr | 0.80 | 0.80 | Undetected | 0.85 | |
| | 300° F., 5,000 psi for 72 hr | 1.48 | 1.48 | Undetected | 1.69 | No visible cracks |
| | 350° F., 5,000 psi for 72 hr | 1.18 | 1.52 | 0.34 | 0.99 | Minor interface debonding |
| | 400° F., 5,000 psi for 96 hr | 0.48 | 1.41 | 0.93 | 1.27 | Interface debonding |
| EP-2/AS4 | 400° F., 5,000 psi for 96 hr | 1.88 | 3.03 | 1.15 | 2.43 | Severe delamination |
| PH-1/ S2 | Room T&P for 240 hr | 1.06 | | 0.26 | | |
| | 250° F., 5,000 psi for 240 hr | 1.65 | | 1.00 | | |
| | 350° F., 5,000 psi for 240 hr | 1.64 | | 1.17 | | |
| | 400° F., 5,000 psi for 96 hr | 1.65 | 3.29 | 1.64 | 1.05 | Resin and interface cracking |
| HP-2/T300 | 400° F., 5,000 psi for 72 hr | 0.67 | 1.73 | 1.06 | –0.12 | No major cracking |
| TP-1/AS4 | 350° F., 5,000 psi for 240 hr | 0.79 | | | 0.59 | |
| | 400° F., 5,000 psi for 168 hr | 0.76 | 0.70 | Undetected | 0.79 | No cracking, no debonding |

*T&P—temperature and pressure.

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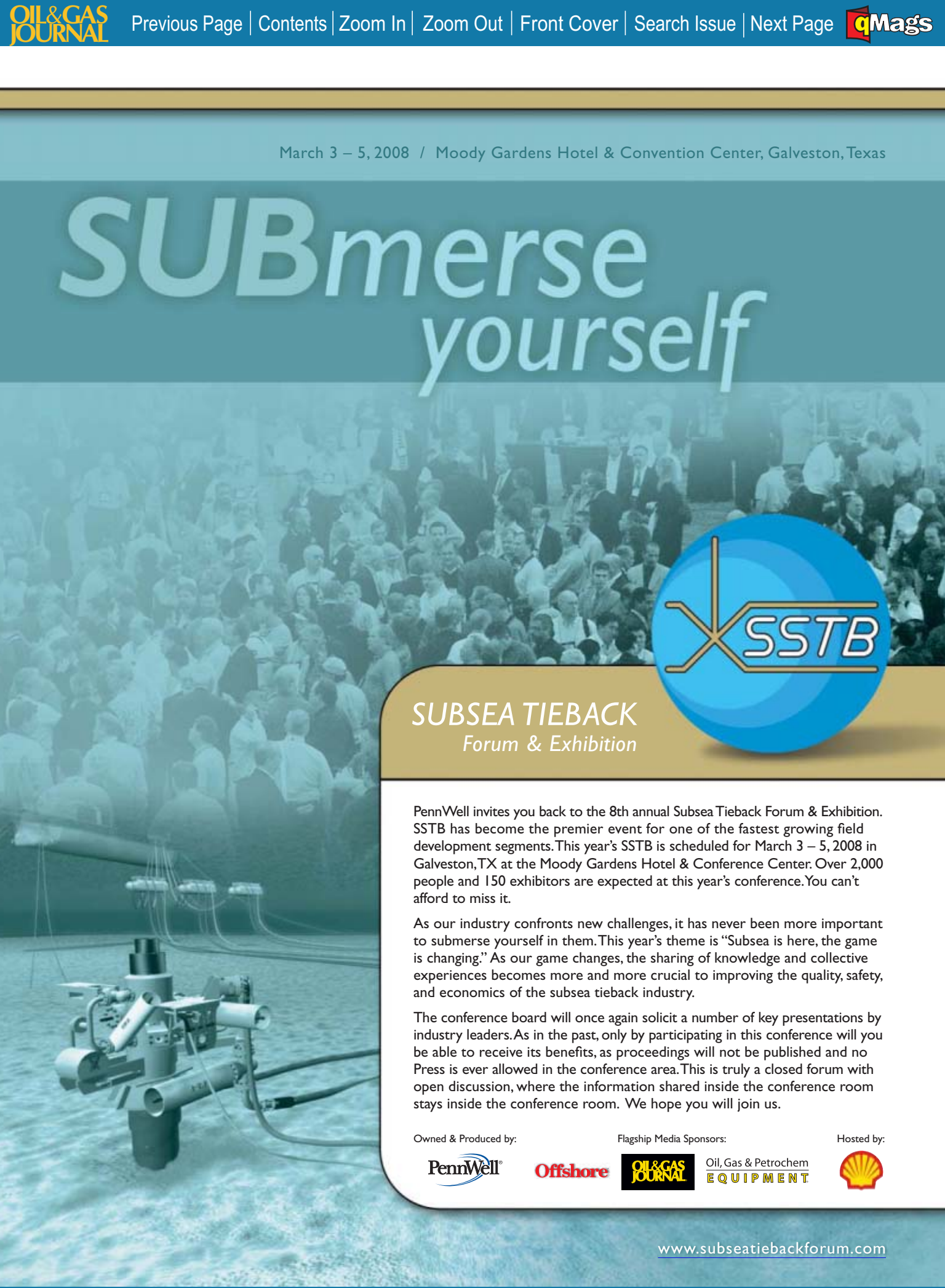

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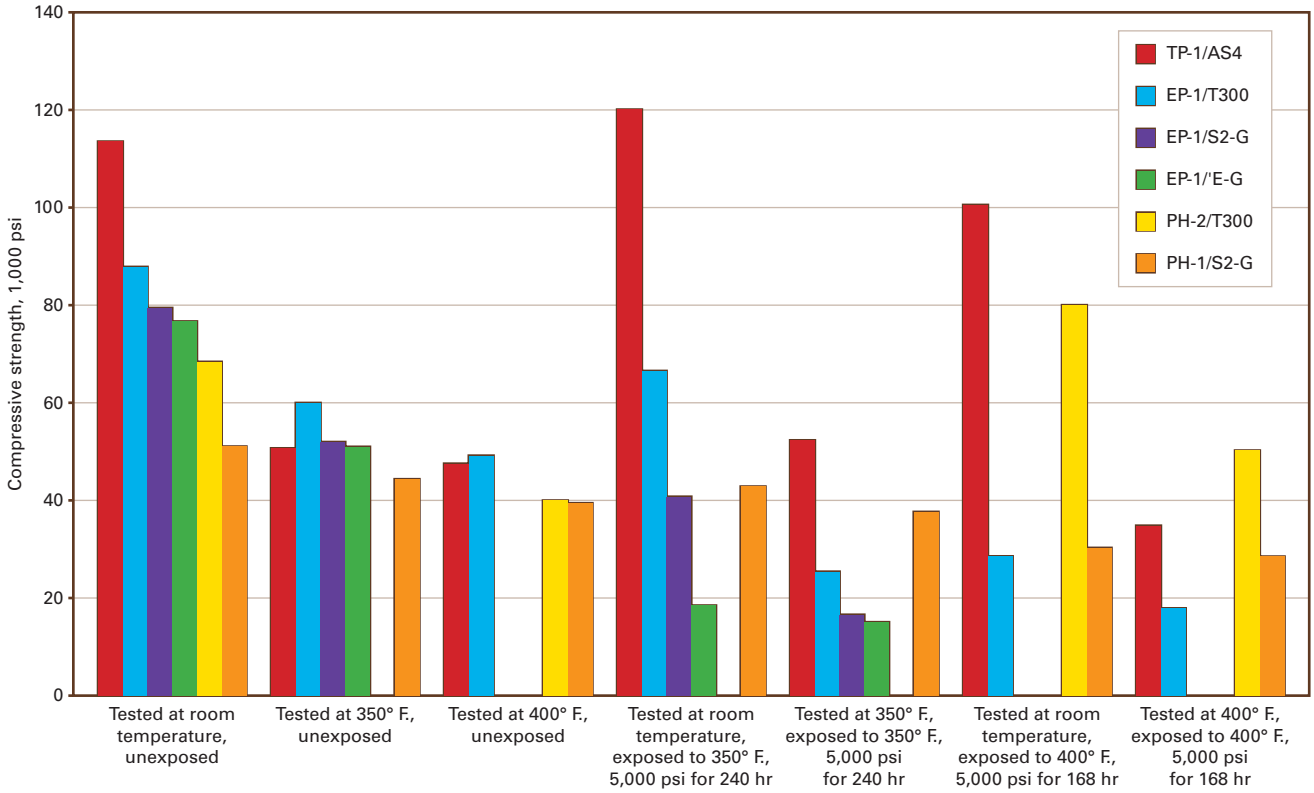
## MEASURED COMPRESSIVE STRENGTH

Fig. 4




conducted before and after the environmental exposure according to ASTM standards D3039 and D6641, respectively.

- Microstructure examinations of the laminate samples before and after the environmental exposure.

### *Water absorption, sample leaching*

Table 2 lists the measured net weight changes, water absorption, sample leaching, and thickness changes of the selected composites after exposure in 3% NaCl brine in the specified temperature and pressure conditions.

When the exposure temperature is at 300° F. or cooler, the tests found no sample leaching from the tetra-functional epoxy composites. Also the water absorption and related dimensional changes behave regularly and are accelerated by the temperature.

Exposure at greater than 300° F., however, activated sample leaching along with the possible damage initiation and development in the exposed composite samples. The sample net weight gain, water absorption, and related dimensional changes may show an irregular behavior depending on the material system and the degree of leaching and internal damage.

Exposure temperature that reached 400° F. damaged all the epoxy-matrix composite samples. The tests found severe delamination in an EP-2/AS4 laminate and substantial fiber-resin interface debonding in an EP-1/T300 laminate (Figs. 2a-2b).

A comparison of the measured data from the composite samples EP-1/E-G, EP-1/S2-G, and EP-1/T300 showed that the glass fiber-reinforced EP-1 composites absorb more water and have more swelling than the carbon fiber-reinforced EP-1 composite, especially when the exposure temperature approaches 350° F.

The mechanisms causing this difference may be the hydrophilic nature of the glass fibers and the osmotic pressure built up by the dissolution in the glass fibers during the fiber and resin debonding process in a high-temperature brine.

Phenolic resins are commonly known to possess low moisture intake and good moisture resistance. PH-1/S2-G, however, has much higher water absorption than its epoxy counterpart EP-1/S2-G when both are exposed in the 3% NaCl brine at room temperature. This indicates that a higher void or microcrack content may exist in the unexposed phenolic composite samples.

PH-2/T300, however, possesses low water absorption, low sample leaching, small dimensional change, and good hygrothermal cracking resistance up to the 400° F. hot-wet exposure. A high-magnification micrograph of a 400° F. hot-wet exposed PH-2/T300 sample shows good microstructure retention (Fig. 2c).

Carbon fiber-reinforced thermoplastic aromatic polyetherketone composite, TP-1/AS4, has the lowest water

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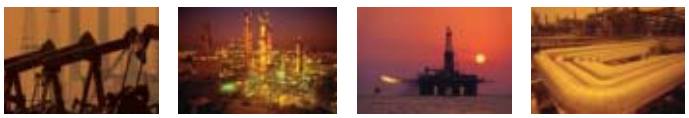

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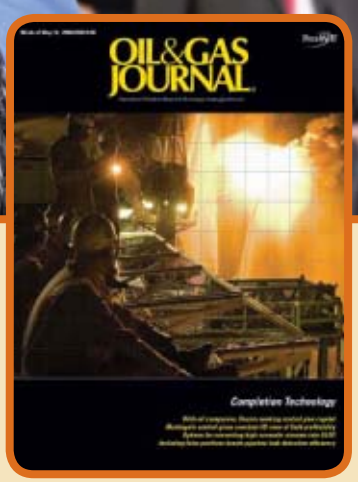


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absorption and dimensional changes. The tests found no sample leaching and hygrothermal cracking after the hot-wet exposure up to 400° F., indicating that the semicrystalline thermoplastic polymers possess the best HT-HP hot-wet environmental resistance.

## Glass transition temperature

Table 3 shows the measured $T_g$ of selected high-temperature polymer composites EP-1/T300, EP-2/AS4, PH-1/S2-G, PH-2/T300, and TP-1/AS4 before and after the HT-HP hot-wet exposure. The data indicate that the moisture effects on $T_g$ depend on the matrix resin type.

**GLASS TRANSITION TEMPERATURE, $T_g$** Table 3

| Material system | Dry $T_g$, unexposed, °F. | Wet $T_g$, exposed in 3% NaCl brine — at 250° F. | at 350° F. | at 400° F. |
|---|---|---|---|---|
| | | 5,000 psi for 240 hr, °F. | | |
| EP-1/T300 | 453-465 | 340-358 | 275-302 | 359-385 |
| EP-2/AS4 | *548 | — | — | 379 |
| PH-1/S2 | 498 | 512 | — | — |
| PH-2/T300 | 409 | — | — | 442 |
| TP-1/AS4 | 293 | — | — | 293 |

*Manufacturer published data.

Epoxy resins are characterized with moisture degradation in $T_g$. The degree of the degradation, however, depends on the epoxy chemistry, cure agents, and other additional additives in resin formulations. Although the aromatic amine-cured tetra-functional epoxy is the best hot-wet resistant high-temperature epoxy resin, the tests found substantial wet $T_g$ degradation from the hot-wet exposed carbon fiber-reinforced epoxy composites such as EP-1/T300 and EP-2/AS4.

Characteristics of moisture $T_g$ degradation of phenolic and thermoplastic-matrix composites are different from those of the epoxy-matrix composites. No change in wet $T_g$ from its initial dry $T_g$ was found from the 400° F. exposed thermoplastic composite TP-1/AS4, indicating the superior high-temperature hot-wet resistant capability of the thermoplastic resin.

Furthermore, the tests found increases in wet $T_g$ from their initial dry $T_g$ for the HT-HP hot-wet exposed phenolic composites PH-1/S2-G and PH-2/T300, indicating a continuous cure occurred during the hot-wet exposure process.

## Mechanical properties

Fig. 3 shows the measured tensile strength of the TP-1/AS4, EP-1/T300, EP-1/S2-G, EP-1/E-G, and PH-1/S2-G composites at room temperature, 350° F., and 400° F. before and after the HT-HP hot-wet exposure at 350° F. and 400° F. for 240 hr and 168 hr, respectively.

Tensile strength retention of the carbon fiber-reinforced composites, TP-1/AS4 and EP-1/T300, is fairly good at 350° F. and 400° F. and after the HT-HP hot-wet exposures because tensile strength of a continuous fiber-reinforced composite in a fiber direction is a fiber-dominated property and carbon fibers possess excellent high temperature and hot-wet environmental resistance.

In contrast to the carbon fiber-reinforced EP-1 composite, tensile strengths of the glass fiber-reinforced EP-1 composites, EP-1/S2-G, and EP-1/E-G decrease 70-80% after the hot-wet exposure at 350° F. for 240 hr. This indicates that the hot-wet conditions severely attacked the glass fibers in the EP-1 composites, resulting in tensile strength losses of the glass fiber-reinforced composites.

After the hot-wet exposure at 350° F. and 400° F, the tests showed a similar degradation in tensile strength of the S2-glass fiber-reinforced phenolic composite, PH-1/S2-G (Fig. 3). This degradation, however, is much less severe than that of the S2-glass fiber-reinforced epoxy composite EP-1/S2-G in the same exposure condition. This may indicate that the phenolic resin provides more effective protection to the glass fibers in the composite than the EP-1 epoxy resin.

Fig. 4 shows the measured compressive strengths at room temperature, 350° F., and 400° F. for the TP-1 /AS4, EP-1/T300, EP-1/S2-G, EP-1/E-G, PH-1/S2-G, and HP-3/T300 composites before and after the hot-wet exposure at 350° F. and 400° F for 240 hr and 168 hr. The PH-3/T300 specimen is an exception and it was exposed at 400° F. for 72 hr.

The data in Fig. 4 indicate that temperature effects on composite compressive strength are greater than the effects on tensile strengths, and the effects depend more on the type of resin matrices because the compressive strength of a composite is a resin-matrix dominated property.

Room temperature compressive strength retention of the EP-1/T300 composite after the hot-wet exposure at 350° F. for 240 hr is as high as 76%. It has a 93% retention after exposure at 250° F. for 240 hr. When the exposed wet specimens tested at 350° F, however, the residual compressive strengths decreased dramatically to only about 25,000 psi, 30% retention, even if carbon fibers reinforced the composite.

The mechanism behind this phenomenon is clear. The mechanism is the moisture-induced $T_g$ degradation of the EP-1 epoxy matrix resin after the HT-HP hot-wet exposure (from 465° F. dry $T_g$ to 302° F. wet $T_g$). This moisture-induced thermomechanical degradation is sometimes considered a reversible or partially reversible process without significant irreversible material damage when the exposure temperature is low.

In the case of EP-1/E-G and EP-1/S2-G composites after the hot-wet exposure at 350° F. for 240 hr and in the case of the EP-1/T300 composite after the hot-wet exposure at 400° F. for 168 hr, the room-temperature compressive strength retention is only about 25%, 50%, and 32%, respectively. These exposure-resultant compressive strength losses are not reversible because of the irreversible hygrothermal or hydrolytic damage in glass fibers, in the epoxy resin phase, or at the fiber and resin

interface, as discussed previously.

Fig. 4 does show that although the initial room-temperature compressive strength of the glass fiber-reinforced phenolic composite PH-1/S2-G is much lower than that of the carbon fiber-reinforced epoxy composite EP-1/T300, after the 350° F. hot-wet exposure, its compressive strength at 350° F. becomes much greater than that of the EP-1/T300 composite with a retention rate of about 75%.

This is attributed obviously to the outstanding hot-wet environmental resistance and the wet $T_g$ retention of the PH-1 phenolic resin, as discussed previously. More encouraging is that the carbon fiber-reinforced developmental phenolic composite PH-2/T300 shows much improvement in compressive strength at room temperature and 400° F. after the 400° F. hot-wet exposure.

This was the first time that the compressive strength of a polymer-matrix composite at 400° F. after the 400° F. exposure in 3% NaCl brine for 72 hr reached 50,000 psi.

Fig. 4 also shows that the TP-1/AS4 thermoplastic composite possesses high compressive strength at room temperature and excellent hot-wet environmental resistance with no degradation in 350° F. compressive strength after the 350° F. exposure and limited degradation in 400° F. compressive strength after the 400° F. exposure.

The DMA analysis results of the exposed wet TP-1/AS4 samples support this outstanding hot-wet mechanical performance. The tests, however, found that the compressive strength retention of the TP-1/AS4 composite at 350° F. and 400° F, whether before or after the HT-HP hot-wet exposure, were only 35-47% because of the relatively low $T_g$ (~290° F.) of the TP-1 resin that is much below the test temperatures. ✦

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# Coating heat-transfer equipment enhances operational efficiency

**Edward L. Curran**
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Companies that use coatings to properly maintain and keep their heat-transfer equipment (HTE) clean can realize significant cost savings—in the form of reduced downtime and depreciation on capital equipment, improved energy efficiency, and stronger feed outputs.

Inefficient heat transfer in heat exchangers is a common bottleneck that plagues refineries and energy operations around the world, requiring considerable attention and, at times, and greater-than-anticipated expense.

In refineries, heat exchangers play a critical role in cooling and processing various streams. It is of paramount importance to preserve these systems to ensure they operate at maximum efficiency and prolong their working lives through good maintenance practices.

Because the cost of poorly performing HTE can cost well into the millions of dollars, many operators have usually found it preferable to maintain maximum operation efficiency and extend tube life by coating the inner diameters with phenolic materials.

Although the type of pipe metallurgy and tubular ID coatings can differ between oilfield, refinery, and pipeline applications, a preventive-coatings approach holds many advantages and can save millions in operational costs.

In the past, coating piping ID had to be done in special shops, not on site. That meant each heat exchanger had to be completely disassembled, shipped, and then reassembled; it precluded the largest units from being transported at all.

Progress in techniques has enabled in situ application to be common, and coatings are optimized to match the type of steel service conditions for best effect. Coatings can consist of bisphenol f, fluorinated products, phenolics, and novolacs, depending on the service conditions to which they are applied.

Before coatings, the only way to extend tube life involved chemical cleaning and mechanical cleaning or upgrading to expensive alloys. The chemical cleaning actually produces toxic $H_2S$ gas and hazardous waste, and removing oxides also causes further corrosion due to structural degradation.

## Case study

A US Gulf Coast refinery tracked its heat exchanger costs during a 12-year period. Measuring outages/month for cleaning or leaks at 6-month intervals during January 1993 through January 2005, the company saw visible improvements. The monthly outages were as high as 17 until after July 2001, when they dropped to fewer than 2 outages/month (Fig. 1).

The time between leaks (Fig. 2) also dramatically increased during the period, particularly from January 2002 to March 2004. The number of years between service maintenance for leaks was trending toward 20 years, according to the data; before the coatings were applied, the number of service stoppages was averaging 6.5/month. Outages/month dropped to a mean of less than one in recent years because the most problematic exchangers were coated.

This represents an improvement of 120 fewer service outages and 72 fewer repairs/year. Because the cost of an outage is about $5,000/heat-exchanger bundle, this improvement translates to savings in outages of $600,000/year.

Additionally, repair and replacement costs average $20,000/bundle. With coatings and proper maintenance procedures now in place, this refinery is saving about $1.4 million/year. Combined, the outage and repair savings exceed $2 million/year.

These estimated cost savings do not account for the price of bundle retubings or higher alloy replacements, at about $500,000/incident. Additionally,

the greatest potential economic benefit is maintaining optimal or additional process throughput, which, while harder to quantify, can quickly add vast amounts of net revenue to an existing unit.

In another part of the same company's refinery operations, the $C_4$-recovery unit, several heat exchangers (feed flash condenser, de-ethanizer overhead condenser, ammonia condenser) were historically "bad actors." The heat-exchanger tubes were suffering severe fouling, corrosion, and pitting, which plagued unit reliability and cost due to frequent outages for leak repair and cleaning that cut back feed rates to the FCC units.

Of the six exchangers chosen for coatings, two required complete retubing before coating. The other four were 3 years old at the time but had about 50% remaining tube wall. The company opted to apply coatings to all six heat exchangers to prevent further corrosion from sulfate-reducing bacteria and to decrease fouling from calcium deposits.

By coating all the exchangers, the refiner could use preventive maintenance to reduce further stoppages for leak repairs, retubings, and cleaning cycles.

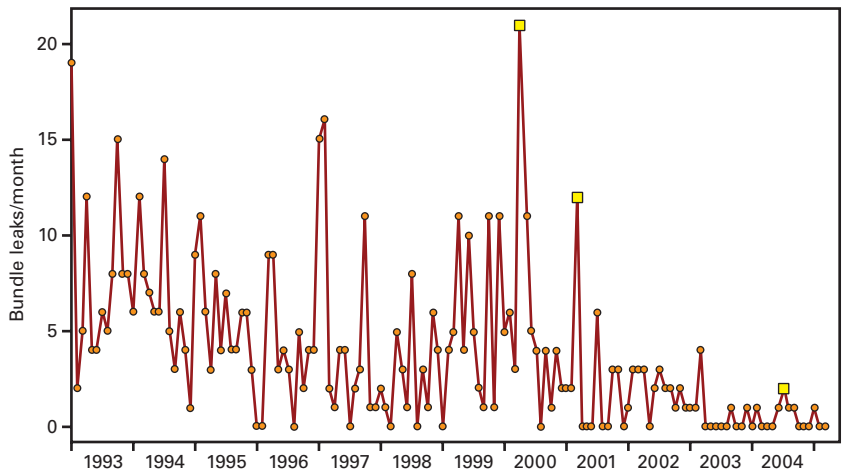
The results due to tube ID coatings included improved FCC gas cooling in the heat exchangers, which ran at more than 230 psi in the older equipment before retubing and coating. After the coated exchangers were put in service, the coolant fluid pressure dropped 10% and remained steady within a range of 190-200 psi.

The additional cooling eliminated all gas recycling and kept the unit at 96% recovery rate even in the hottest summer months. This netted an additional recovery of 1,000 b/d.

Previous cleaning cycles for each exchanger averaged 6 months at 4 days each and lost production of 10,000 b/d. The heat exchangers now have more than 9 years of service and have never been taken out of service for cleaning.

STEEL BUNDLE LEAKS

Fig. 1




## Case study 2

At a US West Coast refinery, the alkylation unit effluent refrigerant condensers had historically created bottlenecks for the butane gas cycle. New or just cleaned exchangers would start with flow rates of 5,000 gpm and quickly decline due to fouling within 6 months to 700 gpm. This forced the 6,000-hp compressor to recycle 30% of the butane.

Two exchangers' IDs were coated in 2004. Since installation, the exchangers maintained flow rates of 5,000

## A history of coatings

Fluids that come into contact with tubular surfaces have always plagued heat-exchanger equipment. Historically, operators used water treatment and periodic cleaning via hydroblasting to manage fouling, but the results were not always optimal.

Users now use polymer coatings on the tubular inner and outer diameters (ID, OD) of heat-transfer equipment. Over the years this practice has evolved and matured into a cost-effective remedy to reduce typical fouling and corrosion problems intrinsic to heat-exchange equipment.

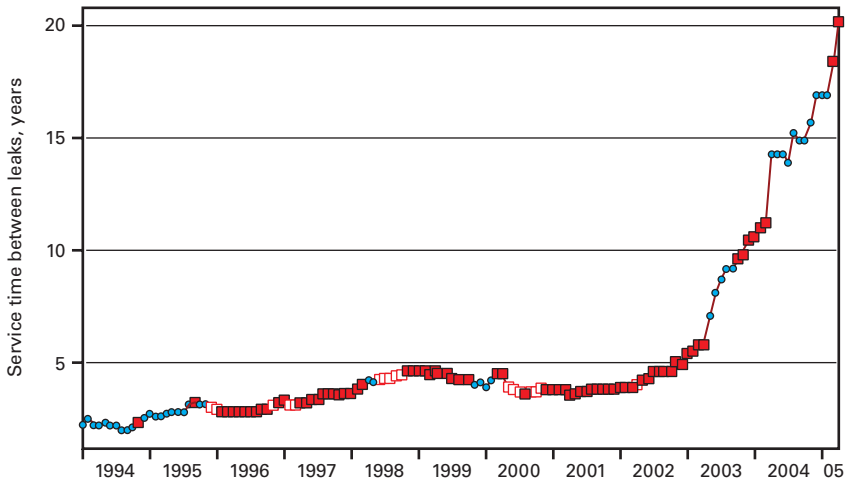
Improvements in materials, surface preparation, application and thermal conductivity, plus owner-operator data collection and analysis, have established tubular coatings as viable heat-transfer equipment problem solvers.

A German chemical company first developed phenolic materials for tube ID coatings in the 1950s. Applied by a fill, drain, and rotate method in a specialized shop, it was the industry's best option until the mid-1980s. By that time, companies in Italy began experimenting with air-atomized spray applications of epoxy phenolic. The Italian companies, by coating the tube ID with the epoxy phenolic compound, achieved excellent results and improved fouling and corrosion resistance to the main condensers, which actually restored the generating units to normal operating capacity.

Today, ID coatings are commonly considered a best practice for extending the performance and lifecycle of a heat-transfer system. It took decades of trial and error in upstream, midstream, and downstream applications to find the right solutions for each ID, bare metal, and chemical coating compound to optimize the practice for each and every condition and situation.

TIME BETWEEN LEAKS

Fig. 2




gpm. Backpressure on the compressor dropped 5 psi, and all gas recycling was eliminated, even on 100° F. days. The unit raised production to 16,500 b/d from 13,000 b/d consistently during the last 3 years.

The tube bundles in the exchangers were each given three or four coats of polymer after being pretreated with grit blasting to ensure their inner surfaces were prepared according to NACE-1 standards for white-metal cleanliness. Grit blasting also creates more surface area so that the coatings can achieve the maximum mechanical bond to the carbon-steel tubes when applied.

Elimination of normal tube wall corrosion issues has also allowed refiners to use lower-cost SA-214 welded tube vs. SA-179 seamless. This cost savings is a significant credit towards the cost of the coating application.

The refiner expects a 10-year minimum coating life, barring some minor tube-sheet touchups during maintenance periods. After a decade, the tube bundles can be grit-blasted and recoated if needed. The life of the HTE should exceed 20 years and can be continued indefinitely with repeated coating applications.

## Coating materials

Decades of service history (see box, p. 65) have shown that tube coatings can enhance heat transfer and overall performance significantly.

Common coatings used for the heat exchanger ID coating include baked phenolics, epoxy phenolics, vitons, novolacs, and thermoplastics. Coatings are chosen according to the service temperature and conditions, and whether they are applied in the shop or the field.

One of the best-known coatings for oilfield applications is a thermoplastic, polyphenylene sulfide (PPS). It is a viable thin-film corrosion barrier for tubular products that can function well even at temperatures exceeding 400° F. It provides excellent protection to carbon-steel substrates and serves as a good alternative to an alloy.

It is being developed and used as the next generation of coatings for HTE. PPS can be combined with Teflon and other pigments to create a thermally conductive, self healing, thin-film thermoplastic that can operate at 400° F. continuously.

Polymer tube linings have always suffered from the perception of heat-transfer penalties due to lower thermal conductivities. Although the coating's thermal conductivity is less than the parent tube, several factors offset these effects.

The first factor covers normal design considerations. Generally, heat exchangers are designed with a certain fouling factor (0.001-0.002 btu/hr). Coating to the tube ID lowers the thermal duty by 0.0006-0.0008 btu/hr, which is well below the precalculated design. Applying the coating either totally eliminates the subsequent fouling or greatly reduces the accumulation of typical micro- and macro-fouling, mitigating the initial design consideration.

The second major factor is the boundary-layer drag reduction. About 70% of total heat-transfer resistance across a heat exchanger tube is the slow-moving fluid coming into contact with the tube wall. Friction at the tube wall reduces this flow and creates an insulating barrier of low-velocity fluid.

Polymer coatings reduce the surface tension at the tube wall substantially—by a factor of 30-40 dynes/sq cm vs. bare steel or metal alloy in a non-

oxidized or new condition. Reducing friction reduces the boundary-layer drag and substantially opens up the flow profile.

## Bottom-line benefits

Applying polymer coatings to the ID of HTE in refineries can provide benefits that increase heat-transfer duty, eliminate corrosion, reduce or eliminate micro- and macro-fouling, improve the cleaning cycle, and allow for perpetual equipment life with recoating.

Certain chemical environments, elevated temperatures, and high fluid or gas velocities can limit the efficacy of coatings. Benefits, however, can be realized with coatings in the acceptable temperature and exposure that correspond to the coating properties, guided by quality-assurance techniques.

Video scopes can verify and test surface cleanliness for grit blasting. Chloride testing is also viable, but usually on tube-sheet areas. Blotter tests or black-light examinations can confirm or eliminate the presence of hydrocarbons.

The most limited quality-assurance issue centers on dry-film thickness readings. Current instrumentation can only reach 6 in. into the tube-end to verify adherence to the specification. If additional verification is needed, sample tubes can be coated, split, and measured for verification of minimum dry-film thickness throughout the tube.

Holiday testing can then be accomplished with a low voltage, wet-sponge method, adapted to extend all the way through the tube, with the sponge sized to fit snugly into the tube's ID.

There are now more approaches to produce the desired outcomes and reduce the losses incurred through inefficient heat transfer in oilfield applications, pipeline transmission, and refining. The best starting point is to consider the various conditions and use the most efficient methods to clean and coat the tubular systems.

Reduced downtime, slower depreciation on capital, assets and equipment, fewer stoppages due to repairs or outages, and better maintenance procedures all contribute to improved operational efficiency, gains in production capacity and, ultimately, higher margins. Coating HTE tubes can yield significant returns on capital investment. ✦

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# Study calls for pipeline filler metal improvement

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Filler metals for 36Ni alloy cryogenic pipeline construction need further refining to obtain overmatching mechanical properties relative to the base metal.

This article provides an overview of mechanical properties for commercially available filler metals for 36Ni alloy construction, helping determine loading limits and performance capabilities of the various filler metals available. Two of the alloys tested meet the specified property values, but none overmatched both the tensile and impact properties of the base metal at room and cryogenic temperature.

## Background

Operators of LNG loading terminals want to change loading pipeline design from the standard jetty-based stainless steel to a subsea 36Ni alloy-based design. Changing pipeline materials from stainless steel to a 36Ni alloy would allow elimination of the jetty structure and expansion loops in favor of a straight subsea pipeline, decreasing the materials required, reducing environmental disturbance, and increasing the security of the pipeline.

The 36Ni's low coefficient of thermal expansion, about 10 times lower than stainless steel, allows these improvements, decreasing thermal stresses that arise when the pipeline is cooled from ambient to operating temperature. Traditional LNG offloading lines compensate for these thermal stresses by including mechanical expansion loops and bellows that can deflect with the thermal stresses. Moving away from the traditional method could reduce operating expenses of the LNG offloading terminal by extending the LNG pipeline to deeper water, reducing the amount of required loading berth access dredging.

Development of 36Ni as a pipeline material is ongoing. Determining a weld filler metal for both pipe fabrication in the mill and pipeline installation in the field that can withstand the stresses from installation and service is a critical component of this work. This article aims to identify an existing filler metal class that meets these needs.

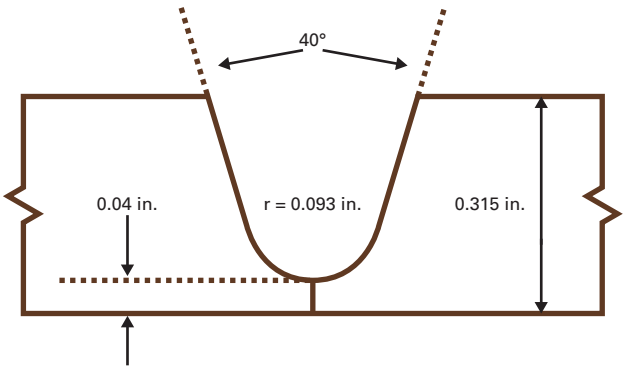
Table 1 lists the five commercially available weld filler wires selected. These filler wires fall into two general categories:

- Matching coefficient of thermal expansion properties.
- Enhanced mechanical properties.

The matching CTE filler met-

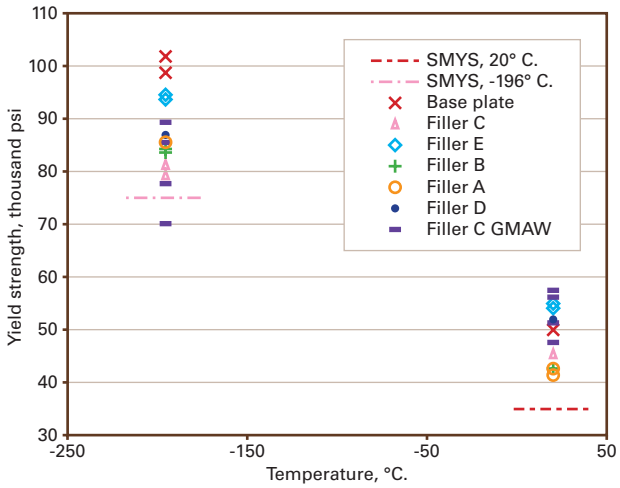
*Based on a presentation to the 2007 Offshore Technology Conference, Houston, Apr. 30-May 3, 2007.*

**BUTT-JOINT WELDING GEOMETRY** Fig. 1



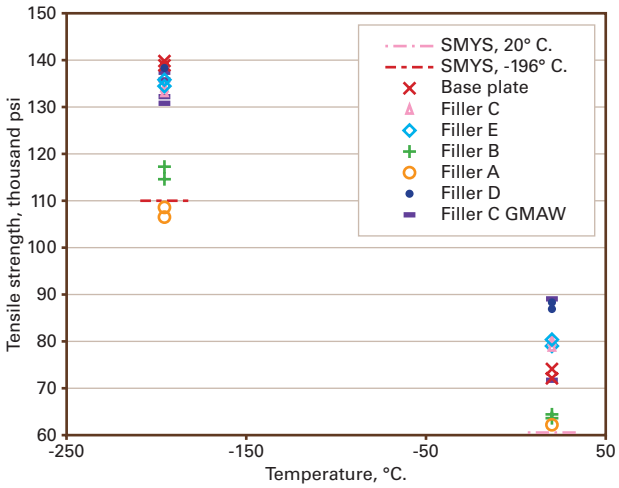
## METAL YIELD STRENGTH

Fig. 2




## METAL TENSILE STRENGTH

Fig. 3




als match the base metal chemistry (36%Ni/bal.Fe) and thus the base metal CTE. The enhanced mechanical property filler metals add alloy elements to improve mechanical strength but also increase the CTE.

The design of matching CTE filler metals focused on applications where CTE matching with the base metal was critical. The enhanced mechanical property filler metals address applications where load-bearing conditions require a filler metal that possesses thermal properties close to the base metal, but where mechanical strength is of primary importance.

A higher weld strength than the base metal yields the preferred case, allowing structures to be designed with the base metal properties as the limiting factor

Table 2 lists proposed minimum weld mechanical properties.

## FILLER METALS

Table 1

| | Matching | | Alloyed | | |
|---|---|---|---|---|---|
| ID | A | B | C | D | E |
| Additional elements | — | — | Nickel, titanium, aluminum | Titanium, niobium, silicon | Niobium, carbon, manganese, titanium |

## PROPOSED MINIMUM WELD MECHANICAL PROPERTY VALUES

Table 2

| Property | 20° C. | –196° C. |
|---|---|---|
| 0.2 yield strength | 35 kg/sq in. | 75 kg/sq in. |
| Tensile strength | 60 kg/sq in. | 110 kg/sq in. |
| Elongation | 18% | 18% |
| Charpy, weld center line | -- | 39 ft-lb |
| Charpy, fusion line | -- | 39 ft-lb |
| Charpy, FL +2 mm | -- | 39 ft-lb |
| Charpy, FL +5 mm | -- | 39 ft-lb |

## Experimental procedure

A series of plate butt welds provided mechanical test samples to investigate the properties of a variety of commercially available filler metals. All weld wires listed in Table 1 were subjected to gas tungsten arc welds. Table 3 lists the welding parameters for the GTAW welds. Welding the C filler metal via a GMAW process as well determined the effect of the welding process on weldment mechanical properties.

Fig. 1 illustrates the weld bevel geometry.

Table 4 lists the GMAW welding process parameters.

Mechanical tests of the welds complied to requirements similar to those in DNV Offshore Standard DNV-OS-F101, Appendix C, Section F as a basis for weld consumable comparison.[1] The following analytical methods studied the 36Ni weldment mechanical properties.

## Tensile testing

Tensile tests recorded the stress-strain curve of the solidified weld metal as well as the composite weldment.

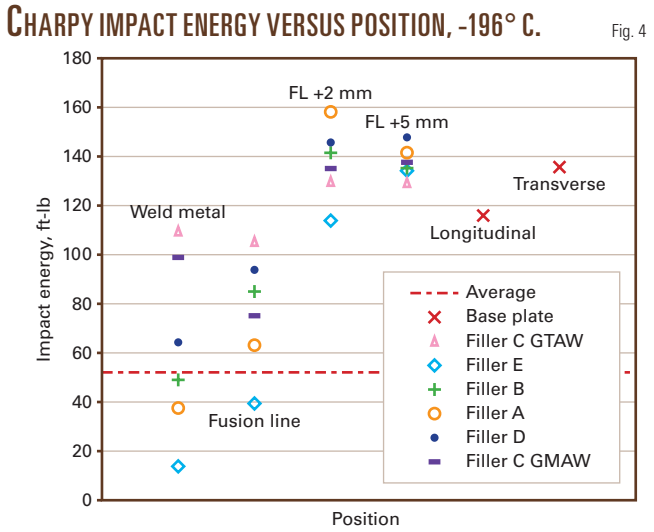
Round tensile bars (6-mm gauge diameter) machined from the solidified weld pool characterized the all-weld metal samples according to ASTM A370.[2] Tests used four tensile samples per filler metal, two each at room temperature and at –196° C., encompassing the full range of temperatures to which the materials would be exposed during construction and service.

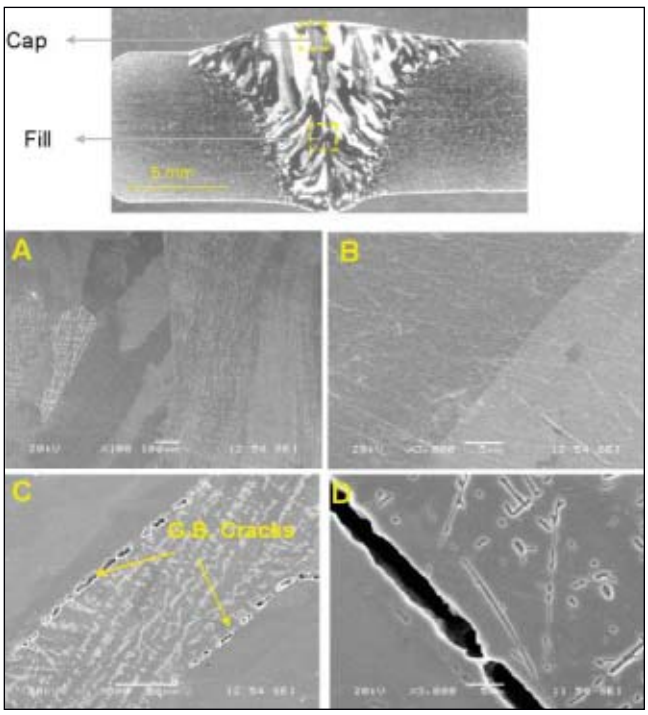
Table 2 lists the minimum values regarded as acceptable, recording values of 0.2% yield stress, tensile stress, and elongation.

Flat bar samples machined from the base metal with the weld oriented normal to the sample length characterized the tensile properties of the complete weldment. Removing the weld reinforcement cap from these samples gave dimensions consistent with ASME IX,[3] reporting values of 0.2% yield stress, tensile stress, and elongation.

## Impact testing

ASTM E 23 guided Charpy impact tests on each of the welds at –196° C to measure the weldment toughness under




*SEM images portray cracking evidence in filler metal B. Sections A and B, micrographs from the cap pass, show no cracking. Sections C and D, micrographs from the fill passes, show grain boundary cracking (Fig. 5).*

simulated service conditions.[4] Samples prepared from each weld located the sample notch at the weld center line, weld fusion line, 2 mm into the base metal, and 5 mm into the base metal. Separate Charpy impact tests on the base plate compared it to the welded samples, testing three samples at each location.

Table 2 lists the minimum energy absorbed as 39 ft-lb at −196° C.

## Bend testing

Bend testing sample lengths of the welds with both the weld root and weld face exposed tested ductility according to ASME IX,[3] bending the samples through 180° over a 4T radius and accepting or rejecting samples based on the presence of surface cracks.

## Thermal expansion

Section 10 of ASTM E8315 provided the basis for testing the thermal expansion properties of the weld materials across a temperature range of −193 to 22° C.

## Metal cracking

Matching 36Ni filler metals exhibit ductility dip cracking in multipass welds such as those used in this article.[6-10] Metallographic samples examined the weld cross sections for cracking evidence within the weld material via scanning electron microscopy at ExxonMobil Research and Engineering Co.'s Corporate Strategic Research Laboratory, Clinton, NJ.

## Base metal

The tensile stress, 0.2 yield stress, elongation, and Charpy-impact energies recorded at room and cryogenic temperatures parallel to and normal to the rolling direction for the unwelded base plate compared the weldment properties to those of the base metal.

### GAS TUNGSTEN ARC WELD PARAMETERS

Table 3

| Number of passes | 8-10 |
|---|---|
| Electrode size, in. | 0.045 |
| Tungsten size, in. | 0.125 |
| Shield-purge gas | 100% argon |
| Shield gas flow rate, cfh | 30 |
| Purge gas flow rate, cfh | 20 |
| Amps | 125-200 |
| Volts | 8.0-13.5 |
| Travel speed, in./min | 6-8 |
| Bead technique | Stringer |

### GAS METAL ARC WELD PARAMETERS, ALL PASSES

Table 4

| Travel direction | Downhill |
|---|---|
| Travel speed | 12±25% in./min |
| Electrode diameter | 1.2 mm |
| Wire feed speed | 200 in./min |
| Gas flow rate | 65 cfh |
| Shield gas | 85% argon, 15% $CO_2$ |
| Amps | 100-150 |
| Volts | 21-23 |

## Results

Table 5 lists spectroscopically analyzed as-deposited weld compositions.

Fig. 2 shows the yield strengths of the filler wires and base plate at room temperature and at −196° C. A horizontal line at both temperature marks the specified minimum yield stress at 0.2% offset. At room temperature, filler metals C GMAW, D, and E meet or slightly exceed the base metal yield strength, while filler metals A, B, and C GTAW undermatch the base metal. All filler metals undermatched yield strength in cryogenic tests. Data for filler metal C GMAW have significantly more scatter at both temperatures than GTAW process results.

Fig. 3 illustrates tensile strengths of the filler wires and base plate at room temperature and at −196° C. A horizontal line shows specified minimum tensile strength at both temperatures. Room temperature data show that filler

metals C GMAW, C GTAW, D, and E exceed the tensile stress of the base metal. At −196° C. only D matches the tensile stress of the base metal. All other filler metals undermatch. Filler metal A does not meet SMTS.

Fig. 4 presents the energy absorbed vs. the Charpy notch location for the weld filler metals at −196° C. The Charpy notch location varies from the weld center line through the fusion line into the base metal. A general decrease in toughness emerges from the base metal into the weld metal. Only filler metal C's toughness values remain relatively constant across the weld and heat-affected zone.

The E filler metal failed to meet specified minimum toughness values.

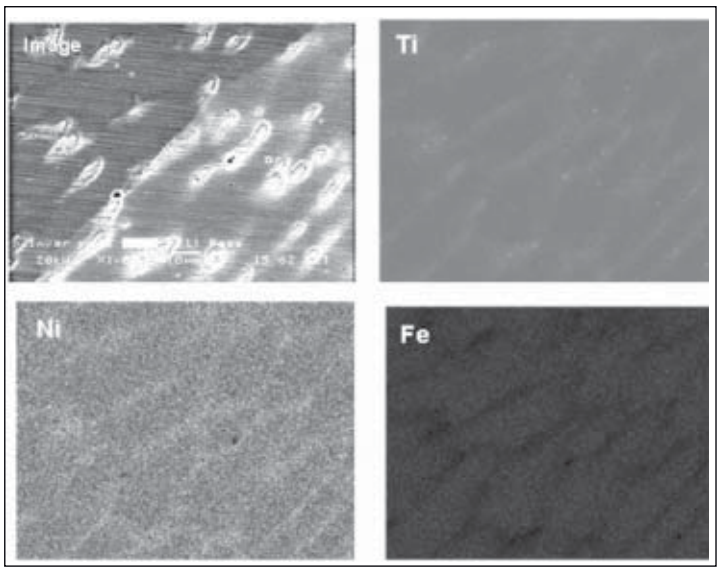
All filler metals passed the bend test with no cracking evidence on the face or root of the weld.

Table 6 lists the measured values of CTE for the weld filler metals. These values fall into two groups:

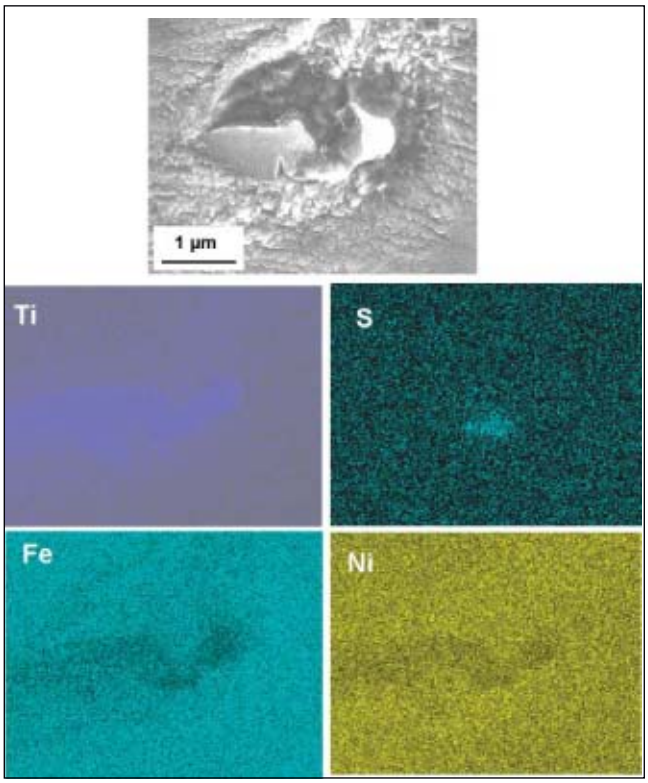
- Those that closely match the 1.6-1.8 x $10^{-6}$ m/m/°C. CTE of the 36Ni base metal (filler metals A, B, and E)
- Those that have about twice the value of the base metal CTE (filler metals C and D).

Examining the weld microstructures of filler metals C GTAW, C GMAW, D, and E found that they did not exhibit ductility dip cracking. Filler metals A and B did. Fig. 5 shows a representative microstructure of a cracked weld pool. Cracked samples had a crack-free final cap pass.

Examination of the the alloyed filler metals by scanning electron microscope uncovered secondary phases. The energy dispersive x-ray spectroscopy SEM images of Fig. 6 show an example from filler metal C. The greater brightness of these images shows higher composition of the element mapped.




*SEM EDS mapping shows titanium-rich particles in the fusion zone microstructure of filler metal C (Fig. 6).*




*High-resolution imaging and EDS mapping show a titanium-rich second phase particle in filler metal C's fusion zone (Fig. 7).*

Fig. 7 shows a high-magnification image and x-ray spectroscopy mapping of a single particle from Fig. 6. The titanium-rich particle is also rich in sulfur.

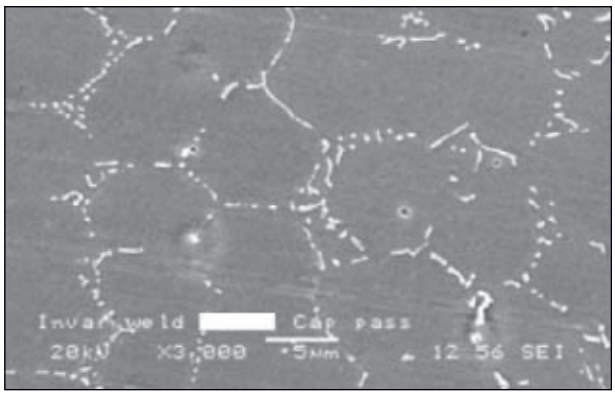
Fig. 8 shows NbC particles found decorating the grain boundaries of filler metal E's fusion zone.

Figs. 2-4 show that the goal of overmatching baseplate mechanical properties at both cryogenic and room temperatures was not uniformly achieved with any of the filler-metal alloys. Certain filler metals would match or overmatch for one property but not another or overmatch at one temperature but not the other.

CTE-matching filler metals A and B showed ductility dip cracking. Filler metal A showed 50% of its grain boundary area cracked, while filler metal B had 90% of its fusion zone grain boundaries cracked, evinced by the presence of 10-500-µm cracks on the grain boundaries of the fusion zone in Fig. 5C and 5D. These cracks lie within weld passes that are reheated by subsequent welding but are not present in the final cap pass.

Examining the as-deposited weld compositions in Table 5 can explain the formation of these cracks. Literature links ductility dip cracking to the sulfur and phosphorus content of the fusion zone.[6-9] One study found ductility dip cracking to increase dramatically when phosphorus content was above 0.004%.[8] Table 5 shows that all of the weld pools contained phosphorus at levels of 0.007% or more, yet only CTE matching filler metals A and B cracked.

None of the enhanced mechanical property filler metals showed ductility




*SEM imaging of filler metal E's fusion zone microstructure shows niobium-carbon particles on grain boundaries (Fig. 8).*

## AS-DEPOSITED COMPOSITIONS, GTAW WELDS

Table 5

| | Matching filler metals, % | | Alloyed filler metals, % | | |
|---|---|---|---|---|---|
| | A | B | C | D | E |
| Nickel | 37.9 | 38.38 | 46.64 | 39.64 | 38.08 |
| Chromium | 0.05 | 0.06 | 0.02 | 0.02 | 0.08 |
| Titanium | <0.01 | <0.01 | 2.04 | 0.83 | 0.25 |
| Niobium | <0.01 | <0.01 | <0.01 | 2.14 | 1 |
| Carbon | 0.02 | 0.03 | 0.02 | 0.02 | 0.18 |
| Silicone | 0.23 | 0.2 | 0.06 | 0.87 | 0.05 |
| Molybdenum | <0.01 | <0.01 | <0.01 | 0.03 | <0.01 |
| Copper | 0.03 | 0.04 | 0.03 | 0.04 | 0.02 |
| Aluminum | <0.01 | <0.01 | 0.15 | 0.02 | 0.08 |
| Manganese | 0.32 | 0.32 | 0.11 | 0.27 | 0.7 |
| Sulfur | 0.001 | 0.001 | <0.001 | 0.002 | 0.001 |
| Phosphorus | 0.007 | 0.008 | 0.007 | 0.007 | 0.008 |
| Cobalt | 0.03 | 0.04 | 0.03 | 0.07 | 0.02 |
| Iron | Balance | Balance | Balance | Balance | Balance |

dip cracking.

Figs. 6 and 7 show second-phase titanium-rich particles of filler metal C not present in the microstructures of matching CTE filler metals A and B. These titanium-rich particles absorb the tramp elements that cause the cracking seen in filler metals A and B. Filler metal E, while exhibiting no ductility dip cracking, showed very low toughness (Fig. 4).

Very high niobium and carbon levels in the weld pool (Table 5) cause NbC particles to form on the weld grain boundaries (Fig. 8). While NbC particles are advantageous for certain applications, in large amounts these hard particles act to decrease weld toughness.

Among the five tested alloys, two filler metals—C and D—exceeded all specified minimum criteria and passed the weld-cracking test. Filler metal C showed the most consistent Charpy v-notch toughness values, but its yield strength was one of the lowest. Filler metal D showed the highest tensile strength values, overmatching at room temperature and matching plate values at cryogenic temperature. Its toughness values, however, showed a sharp decrease at the weld center line.

The welding detailed in Tables 3 and 4 was designed to provide the highest quality and consistency for comparison among different weld metals and not to obtain the highest mechanical properties for individual filler metals. Further refinement could improve individual mechanical properties, as evinced by comparing GTAW and GMAW for filler metal C.

Scatter exists in the GMAW results, shown by the nearly 20,000 psi variation in cryogenic 0.2 yield stress. The GMAW tensile stress and yield stress values, however, are generally higher than the GTAW.

Even though further welding process optimization could increase the property values of some filler metals, the overall comparison between them is valid.

This article further demonstrates the susceptibility of this alloy class to weld-cracking phenomena discussed elsewhere in the literature.[6-9] The presence of ductility dip cracks precluded selection of a filler metal for cryogenic pipeline applications. The large number of weld passes (8-10) for the joint thickness (0.315 in.) may have enhanced the cracking phenomenon in filler metals A and B over that seen in an optimized welding schedule of 4-5 passes for the thickness.

## COEFFICIENT OF THERMAL EXPANSION VALUES

Table 6

| Filler metal | CTE, $\times 10^{-6}$m/m/°C. |
|---|---|
| A | 1.5 |
| B | 1.6 |
| C GTAW | 2.6 |
| C GMAW | 3.4 |
| D | 3.6 |
| E | 1.8 |

Such process refinement, however, was beyond the scope of this work. ✦

## References

1. DNV-OS-F101, "Submarine Pipeline Systems," pp. 120-122, January 2000.

2. ASTM A370–05, "Standard Testing Methods and Definitions for Mechanical Testing of Steel Products," 2005.

3. ASME Section IX, "Boiler and Pressure Vessel Code Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators," July 1, 2005.

4. ASTM E23–06, "Standard Test Method for Notched Bar Impact Testing of Metallic Materials," June 2006.

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6. Kazutoshi, N. et al., "Hot Cracking and its Prevention in Multi-Pass Weld Metal of Fe-36%Ni Invar Alloy," 7th International Symposium, Joint Welding Society, Kobe, Japan, Nov. 20-22, 2001.

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8. Yushchenko, K.A., et al., "Formation of hot cracks in welds in welding Invar alloy," Paton Welding Journal, Vol. 1, No. 10, pp. 724-729, 1989.

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10. Beranger, G. et al., "The Iron-Nickel Alloys," pp. 175-191, Lavoisier Publishing, New York, 1996.

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## New line of resilient seated butterfly valves

The new line of ST Series resilient seated butterfly valves offers high flow coefficients, ISO top mounting, one-piece body with self-centering disk, and a selection of direct mount actuators and gear operators.

Valves are also available as a manual type with limit switches for those uses that do not require automation but do require feedback to a PLC or network bus system.

Valves are available in sizes 2 through 12 in. with a pressure rating up to 225 psi and 14 through 24 in. have a pressure rating up to 160 psi.

The ST Series features a one-piece, ductile iron body. The fusion bonded epoxy body coating offers superior exterior corrosion resistance, the firm says. Also, since no gasket is required for mounting between flanges, additional gaskets or O-rings are not needed for installation. Valves are available with either Buna-N or EPDM seat. A 316 stainless steel disk is standard. Bronze and ductile iron disks are also available. The spherically machined and hand polished disk edge provides a bubbletight shutoff at minimum torque and improves overall endurance by extending the seat life, the company notes.

Source: **Assured Automation,** 19 Walnut Ave., Clark, NJ 07066.

## Two new heavy duty wrench lines

Two new lines of engineers' wrenches and leverage wrenches and an expanded lineup of striking wrenches are available to the industry.

Open-end engineers' wrenches include 15° head sets that allow quick repositioning of the wrench on the fastener. Their lengths—up to $23^{13}/_{16}$ in. long—provide high leverage and extend users' reach into hard to access locations. They come in 13 metric sizes with a black oxide finish.

Leverage wrenches range in length from 2 to 14 in. and are designed for use with detachable handles up to 33 in. long. They come in 11 metric sizes with 4 interchangeable handles.

The firm has added 5 sizes to its line of straight striking wrenches and 15 to its offset line.

Source: **Stanley-Proto,** 480 Myrtle St., New Britain, CT 06053.

## New process pressure gauge

The new 1200 series (ASME grade 2A) pressure gauges each provide the capabilities necessary to monitor pressures in nearly every type of process.

In basic applications, the Type 1259 is suited for years of dependable service, the company says. In more rigorous installations, the Type 1279 Duragauge pressure gauge is designed for use in the presence of harsh pressure media, fire hazard, or extreme cycle volumes. Add pulsation and vibration, and the Type 1279 Duragauge PLUS! pressure gauge offers patented technology to dampen pointer flutter without the need for liquid fill.

Source: **Ashcroft Inc.,** 250 E. Main St., Stratford, CT 06614-5145.

## Imports of crude and products

| | Districts 1-4 | | District 5 | | Total US | | |
|---|---|---|---|---|---|---|---|
| | 8-24 2007 | 8-17 2007 | 8-24 2007 | 8-17 2007 | 8-24 2007 | 8-17 2007 | *8-25 2006 |
| | 1,000 b/d | | | | | | |
| Total motor gasoline | 929 | 828 | 64 | 99 | 993 | 927 | 1,183 |
| Mo. gas. blending comp. | 506 | 589 | 19 | 12 | 525 | 601 | 703 |
| Distillate | 265 | 394 | 55 | 34 | 320 | 428 | 360 |
| Residual | 702 | 218 | 51 | 29 | 753 | 247 | 263 |
| Jet fuel-kerosine | 106 | 180 | 97 | 103 | 203 | 283 | 266 |
| Propane-propylene | 172 | 186 | 6 | 0 | 178 | 186 | 360 |
| Other | 781 | 376 | 46 | 135 | 827 | 511 | 543 |
| **Total products** | **3,461** | **2,771** | **338** | **412** | **3,799** | **3,183** | **3,678** |
| **Total crude** | **8,660** | **9,657** | **1,162** | **1,158** | **9,822** | **10,815** | **11,153** |
| **Total imports** | **12,121** | **12,428** | **1,500** | **1,570** | **13,621** | **13,998** | **14,831** |

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

## Purvin & Gertz LNG netbacks—Aug. 31, 2007

| Receiving terminal | Liquefaction plant | | | | | |
|---|---|---|---|---|---|---|
| | Algeria | Malaysia | Nigeria | Austr. NW Shelf | Qatar | Trinidad |
| | $/MMbtu | | | | | |
| Barcelona | 6.73 | 4.61 | 5.93 | 4.51 | 5.28 | 5.90 |
| Everett | 4.84 | 3.01 | 4.56 | 3.11 | 3.57 | 5.13 |
| Isle of Grain | 3.58 | 2.17 | 3.18 | 2.08 | 2.72 | 3.32 |
| Lake Charles | 3.06 | 1.33 | 2.89 | 1.49 | 1.73 | 3.49 |
| Sodegaura | 5.21 | 7.06 | 5.42 | 7.04 | 6.38 | 4.68 |
| Zeebrugge | 6.05 | 4.35 | 5.62 | 4.23 | 4.89 | 5.61 |

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

## Crude and product stocks

| | Crude oil | Motor gasoline | | Jet fuel, kerosine | Fuel oils | | Propane-propylene |
|---|---|---|---|---|---|---|---|
| | | Total | Blending comp.[1] | | Distillate | Residual | |
| | 1,000 bbl | | | | | | |
| PADD 1 | 16,262 | 50,064 | 23,298 | 10,904 | 53,597 | 13,998 | 4,093 |
| PADD 2 | 65,999 | 45,279 | 14,051 | 7,265 | 27,453 | 1,361 | 21,704 |
| PADD 3 | 183,523 | 60,561 | 25,094 | 13,363 | 33,600 | 17,210 | 25,259 |
| PADD 4 | 13,196 | 6,090 | 2,023 | 579 | 2,750 | 376 | [1]2,369 |
| PADD 5 | 54,652 | 30,570 | 21,403 | 10,042 | 12,514 | 5,654 | — |
| **Aug. 24, 2007** | **333,632** | **192,564** | **85,869** | **42,153** | **129,914** | **38,599** | **53,425** |
| **Aug. 17, 2007** | **337,118** | **196,231** | **88,163** | **41,918** | **129,025** | **36,476** | **53,370** |
| **Aug. 25, 2006[2]** | **332,840** | **206,162** | **91,305** | **41,608** | **136,845** | **41,464** | **63,331** |

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

## Refinery report—Aug. 24, 2007

| District | Refinery operations | | Refinery output | | | | |
|---|---|---|---|---|---|---|---|
| | Gross inputs | Crude oil inputs | Total motor gasoline | Jet fuel, kerosine | Fuel oils: Distillate | Fuel oils: Residual | Propane-propylene |
| | 1,000 b/d | | | | | | |
| PADD 1 | 1,549 | 1,501 | 1,919 | 88 | 467 | 125 | 71 |
| PADD 2 | 3,379 | 3,364 | 2,050 | 191 | 1,020 | 50 | 189 |
| PADD 3 | 7,414 | 7,299 | 3,225 | 680 | 1,894 | 302 | 681 |
| PADD 4 | 538 | 533 | 306 | 31 | 166 | 15 | [1]142 |
| PADD 5 | 2,869 | 2,772 | 1,586 | 418 | 611 | 150 | — |
| **Aug. 24, 2007** | **15,749** | **15,469** | **9,086** | **1,408** | **4,158** | **642** | **1,083** |
| **Aug. 17, 2007** | **15,987** | **15,727** | **9,287** | **1,457** | **4,206** | **666** | **1,044** |
| **Aug. 25, 2006[2]** | **16,166** | **15,801** | **9,141** | **1,432** | **4,215** | **588** | **1,038** |
| | **17,447 operable capacity** | | **90.3% utilization rate** | | | | |

[1]Includes PADD 5. [2]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.


## OGJ crack spread

| | *8-31-07 | *9-1-06 | Change | Change, % |
|---|---|---|---|---|
| | $/bbl | | | |
| **SPOT PRICES** | | | | |
| Product value | 87.16 | 77.48 | 9.68 | 12.5 |
| Brent crude | 70.83 | 66.82 | 4.01 | 6.0 |
| Crack spread | 16.32 | 10.66 | 5.67 | 53.2 |
| **FUTURES MARKET PRICES** | | | | |
| **One month** | | | | |
| Product value | 85.80 | 78.68 | 7.12 | 9.0 |
| Light sweet crude | 72.64 | 69.96 | 2.68 | 3.8 |
| Crack spread | 13.16 | 8.72 | 4.44 | 50.9 |
| **Six month** | | | | |
| Product value | 83.12 | 82.66 | 0.46 | 0.6 |
| Light sweet crude | 70.20 | 73.58 | –3.38 | –4.6 |
| Crack spread | 12.92 | 9.08 | 3.84 | 42.3 |

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

## OGJ GASOLINE PRICES

| | Price ex tax 8-29-07 | Pump price* 8-29-07 | Pump price 8-30-06 |
|---|---|---|---|
| | ¢/gal | | |
| (Approx. prices for self-service unleaded gasoline) | | | |
| Atlanta | 235.7 | 275.4 | 284.0 |
| Baltimore | 224.6 | 266.5 | 290.0 |
| Boston | 221.6 | 263.5 | 290.6 |
| Buffalo | 219.4 | 279.5 | 300.0 |
| Miami | 234.2 | 284.5 | 305.0 |
| Newark | 234.5 | 267.4 | 287.4 |
| New York | 219.4 | 279.5 | 312.3 |
| Norfolk | 223.5 | 261.1 | 269.2 |
| Philadelphia | 227.8 | 278.5 | 306.6 |
| Pittsburgh | 224.7 | 275.4 | 287.3 |
| Wash., DC | 240.0 | 278.4 | 309.4 |
| PAD I avg. | 227.8 | 273.6 | 294.7 |
| Chicago | 241.0 | 291.9 | 341.2 |
| Cleveland | 232.8 | 279.2 | 266.0 |
| Des Moines | 240.6 | 281.0 | 255.1 |
| Detroit | 233.0 | 282.2 | 279.4 |
| Indianapolis | 237.9 | 282.9 | 268.3 |
| Kansas City | 237.5 | 273.5 | 273.3 |
| Louisville | 253.1 | 290.0 | 267.5 |
| Memphis | 246.8 | 286.6 | 273.0 |
| Milwaukee | 232.9 | 284.2 | 298.4 |
| Minn.-St. Paul | 227.1 | 267.5 | 283.2 |
| Oklahoma City | 225.0 | 260.4 | 266.2 |
| Omaha | 236.1 | 282.5 | 272.1 |
| St. Louis | 251.2 | 287.2 | 274.3 |
| Tulsa | 222.5 | 257.9 | 268.5 |
| Wichita | 236.6 | 280.0 | 270.0 |
| PAD II avg. | 236.9 | 279.1 | 277.1 |
| Albuquerque | 237.3 | 273.7 | 290.6 |
| Birmingham | 225.7 | 264.4 | 275.5 |
| Dallas-Fort Worth | 224.0 | 262.4 | 278.7 |
| Houston | 229.9 | 268.3 | 276.8 |
| Little Rock | 224.2 | 264.4 | 275.5 |
| New Orleans | 229.3 | 267.7 | 287.4 |
| San Antonio | 224.0 | 262.4 | 273.2 |
| PAD III avg. | 227.8 | 266.2 | 279.7 |
| Cheyenne | 242.6 | 275.0 | 286.9 |
| Denver | 244.1 | 284.5 | 295.2 |
| Salt Lake City | 243.6 | 286.4 | 294.2 |
| PAD IV avg. | 243.1 | 282.0 | 292.1 |
| Los Angeles | 219.8 | 278.3 | 314.9 |
| Phoenix | 242.7 | 280.1 | 274.5 |
| Portland | 234.0 | 277.3 | 301.2 |
| San Diego | 232.1 | 290.6 | 319.4 |
| San Francisco | 230.4 | 288.9 | 321.9 |
| Seattle | 222.1 | 274.5 | 311.7 |
| PAD V avg. | 230.2 | 281.6 | 307.3 |
| **Week's avg.** | **232.5** | **276.1** | **287.5** |
| **Aug. avg.** | **237.2** | **280.8** | **296.7** |
| **July avg.** | **251.6** | **295.2** | **295.2** |
| **2007 to date** | **228.7** | **272.2** | — |
| **2006 to date** | **223.1** | **266.5** | — |

*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

| | 8-24-07 ¢/gal | | 8-24-07 ¢/gal |
|---|---|---|---|
| **Spot market product prices** | | | |
| Motor gasoline (Conventional-regular) | | Heating oil No. 2 | |
| New York Harbor | 202.00 | New York Harbor | 198.45 |
| Gulf Coast | 198.21 | Gulf Coast | 197.25 |
| Los Angeles | 197.19 | Gas oil | |
| Amsterdam-Rotterdam-Antwerp (ARA) | 189.80 | ARA | 199.05 |
| Singapore | 179.81 | Singapore | 194.29 |
| Motor gasoline (Reformulated-regular) | | Residual fuel oil | |
| New York Harbor | 203.50 | New York Harbor | 126.50 |
| Gulf Coast | 204.25 | Gulf Coast | 136.90 |
| Los Angeles | 205.19 | Los Angeles | 147.00 |
| | | ARA | 127.77 |
| | | Singapore | 135.12 |

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

## BAKER HUGHES RIG COUNT

| | 8-31-07 | 9-1-06 |
|---|---|---|
| Alabama | 6 | 3 |
| Alaska | 4 | 8 |
| Arkansas | 50 | 27 |
| California | 36 | 32 |
| Land | 34 | 29 |
| Offshore | 2 | 3 |
| Colorado | 117 | 92 |
| Florida | 1 | 0 |
| Illinois | 1 | 0 |
| Indiana | 3 | 0 |
| Kansas | 14 | 9 |
| Kentucky | 11 | 7 |
| Louisiana | 179 | 201 |
| N. Land | 64 | 58 |
| S. Inland waters | 23 | 21 |
| S. Land | 27 | 43 |
| Offshore | 65 | 79 |
| Maryland | 1 | 0 |
| Michigan | 3 | 4 |
| Mississippi | 9 | 12 |
| Montana | 16 | 18 |
| Nebraska | 0 | 0 |
| New Mexico | 82 | 88 |
| New York | 6 | 7 |
| North Dakota | 42 | 35 |
| Ohio | 14 | 6 |
| Oklahoma | 198 | 195 |
| Pennsylvania | 17 | 16 |
| South Dakota | 1 | 2 |
| Texas | 853 | 789 |
| Offshore | 6 | 10 |
| Inland waters | 1 | 3 |
| Dist. 1 | 26 | 23 |
| Dist. 2 | 31 | 27 |
| Dist. 3 | 56 | 57 |
| Dist. 4 | 90 | 94 |
| Dist. 5 | 190 | 146 |
| Dist. 6 | 135 | 107 |
| Dist. 7B | 33 | 46 |
| Dist. 7C | 61 | 37 |
| Dist. 8 | 110 | 102 |
| Dist. 8A | 16 | 25 |
| Dist. 9 | 30 | 33 |
| Dist. 10 | 68 | 79 |
| Utah | 42 | 45 |
| West Virginia | 33 | 26 |
| Wyoming | 79 | 106 |
| Others—NV-2; TN-5; VA-3; WA-1 | 11 | 4 |
| **Total US** | **1,829** | **1,732** |
| **Total Canada** | **305** | **505** |
| **Grand total** | **2,134** | **2,237** |
| Oil rigs | 300 | 311 |
| Gas rigs | 1,523 | 1,416 |
| Total offshore | 75 | 93 |
| **Total cum. avg. YTD** | **1,758** | **1,613** |

Rotary rigs from spudding in to total depth.
Definitions, see OGJ Sept. 18, 2006, p. 42.

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

## SMITH RIG COUNT

| Proposed depth, ft | 8-31-07 Rig count | 8-31-07 Percent footage* | 9-1-06 Rig count | 9-1-06 Percent footage* |
|---|---|---|---|---|
| 0-2,500 | 60 | 8.3 | 45 | 2.2 |
| 2,501-5,000 | 103 | 56.3 | 78 | 41.0 |
| 5,001-7,500 | 229 | 23.5 | 241 | 21.5 |
| 7,501-10,000 | 444 | 4.2 | 385 | 5.9 |
| 10,001-12,500 | 440 | 0.9 | 402 | 2.4 |
| 12,501-15,000 | 285 | 0.3 | 303 | — |
| 15,001-17,500 | 114 | — | 108 | — |
| 17,501-20,000 | 68 | — | 73 | — |
| 20,001-over | 35 | — | 31 | — |
| **Total** | **1,778** | **7.9** | **1,666** | **7.0** |
| INLAND | 45 | | 40 | |
| LAND | 1,668 | | 1,561 | |
| OFFSHORE | 65 | | 65 | |

*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]8-31-07 | [2]9-1-06 |
|---|---|---|
| | 1,000 b/d | |
| (Crude oil and lease condensate) | | |
| Alabama | 18 | 20 |
| Alaska | 755 | 628 |
| California | 664 | 677 |
| Colorado | 51 | 59 |
| Florida | 7 | 7 |
| Illinois | 31 | 28 |
| Kansas | 96 | 99 |
| Louisiana | 1,362 | 1,404 |
| Michigan | 14 | 14 |
| Mississippi | 50 | 48 |
| Montana | 94 | 100 |
| New Mexico | 166 | 163 |
| North Dakota | 105 | 112 |
| Oklahoma | 167 | 174 |
| Texas | 1,359 | 1,360 |
| Utah | 44 | 49 |
| Wyoming | 143 | 143 |
| All others | 60 | 71 |
| **Total** | **5,186** | **5,156** |

[1]OGJ estimate. [2]Revised.

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

## US CRUDE PRICES

| $/bbl* | 8-31-07 |
|---|---|
| Alaska-North Slope 27° | 62.00 |
| South Louisiana Sweet | 78.75 |
| California-Kern River 13° | 64.10 |
| Lost Hills 30° | 71.80 |
| Southwest Wyoming Sweet | 68.04 |
| East Texas Sweet | 70.25 |
| West Texas Sour 34° | 64.95 |
| West Texas Intermediate | 70.75 |
| Oklahoma Sweet | 70.75 |
| Texas Upper Gulf Coast | 67.50 |
| Michigan Sour | 63.75 |
| Kansas Common | 69.75 |
| North Dakota Sweet | 66.75 |

*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

| $/bbl[1] | 8-24-07 |
|---|---|
| United Kingdom-Brent 38° | 68.54 |
| Russia-Urals 32° | 66.29 |
| Saudi Light 34° | 66.33 |
| Dubai Fateh 32° | 66.78 |
| Algeria Saharan 44° | 70.45 |
| Nigeria-Bonny Light 37° | 72.11 |
| Indonesia-Minas 34° | 71.65 |
| Venezuela-Tia Juana Light 31° | 64.31 |
| Mexico-Isthmus 33° | 64.20 |
| OPEC basket | 67.98 |
| Total OPEC[2] | 67.52 |
| Total non-OPEC[2] | 66.60 |
| Total world[2] | 67.10 |
| US imports[3] | 65.16 |

[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]

| | 8-24-07 | 8-17-07 | Change |
|---|---|---|---|
| | bcf | | |
| Producing region | 902 | 904 | –2 |
| Consuming region east | 1,657 | 1,613 | 44 |
| Consuming region west | 410 | 409 | 1 |
| **Total US** | **2,969** | **2,926** | **43** |
| | **June 07** | **June 06** | **Change, %** |
| **Total US[2]** | **2,580** | **2,617** | **–1.4** |

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

# Statistics

## WORLDWIDE CRUDE OIL AND GAS PRODUCTION

| | June 2007 | May 2007 | 6 month average production 2007 | 6 month average production 2006 | Change vs. previous year Volume | Change vs. previous year % | June 2007 | May 2007 | Cum. 2007 |
|---|---|---|---|---|---|---|---|---|---|
| | Crude, 1,000 b/d | | | | | | Gas, bcf | | |
| Argentina | 627 | 633 | 630 | 635 | –5 | –0.8 | 130.3 | 134.8 | 752.73 |
| Bolivia | 45 | 45 | 45 | 45 | — | –0.7 | 40.6 | 42.0 | 245.60 |
| Brazil | 1,784 | 1,725 | 1,752 | 1,699 | 53 | 3.1 | 28.0 | 27.5 | 168.00 |
| Canada | 2,631 | 2,576 | 2,616 | 2,442 | 175 | 7.1 | 481.4 | 493.9 | 3,031.15 |
| Colombia | 522 | 521 | 521 | 532 | –11 | –2.0 | 18.0 | 18.0 | 105.50 |
| Ecuador | 500 | 511 | 502 | 542 | –40 | –7.4 | 0.3 | 0.3 | 1.81 |
| Mexico | 3,206 | 3,110 | 3,162 | 3,337 | –175 | –5.2 | 185.8 | 184.0 | 1,072.32 |
| Peru | 117 | 119 | 114 | 113 | 1 | 0.5 | 8.3 | 6.8 | 38.79 |
| Trinidad | 120 | 125 | 123 | 148 | –24 | –16.6 | 110.0 | 118.0 | 680.31 |
| United States | 5,128 | 5,240 | 5,185 | 5,083 | 102 | 2.0 | 1,636.0 | 1,641.0 | 9,707.00 |
| Venezuela[1] | 2,370 | 2,370 | 2,403 | 2,618 | –215 | –8.2 | 70.0 | 72.0 | 437.00 |
| Other Latin America | 78 | 80 | 80 | 79 | 1 | 1.2 | 5.2 | 5.5 | 32.27 |
| **Western Hemisphere** | **17,127** | **17,056** | **17,132** | **17,271** | **–140** | **–0.8** | **2,714.0** | **2,743.8** | **16,272.49** |
| Austria | 17 | 17 | 17 | 17 | — | –1.4 | 4.5 | 4.8 | 30.30 |
| Denmark | 304 | 303 | 311 | 337 | –26 | –7.6 | 17.6 | 19.3 | 134.45 |
| France | 20 | 20 | 19 | 22 | –2 | –11.3 | 3.1 | 3.1 | 17.42 |
| Germany | 68 | 67 | 69 | 71 | –2 | –3.4 | 46.2 | 49.5 | 310.69 |
| Italy | 110 | 111 | 109 | 113 | –3 | –3.0 | 28.0 | 29.0 | 174.30 |
| Netherlands | 44 | 43 | 43 | 29 | 14 | 48.0 | 120.0 | 130.0 | 1,545.00 |
| Norway | 1,921 | 2,181 | 2,301 | 2,533 | –232 | –9.1 | 222.5 | 240.6 | 1,567.84 |
| Turkey | 41 | 41 | 41 | 41 | –1 | –1.6 | — | — | 6.50 |
| United Kingdom | 1,505 | 1,581 | 1,575 | 1,591 | –16 | –1.0 | 182.6 | 241.2 | 1,408.80 |
| Other Western Europe | 3 | 3 | 4 | 5 | –1 | –13.2 | 0.4 | 0.5 | 11.25 |
| **Western Europe** | **4,033** | **4,368** | **4,489** | **4,759** | **–269** | **–5.7** | **624.9** | **717.9** | **5,206.55** |
| Azerbaijan | 900 | 870 | 837 | 587 | 250 | 42.6 | 28.0 | 30.0 | 151.00 |
| Croatia | 16 | 16 | 16 | 17 | –1 | –4.7 | 6.5 | 6.1 | 36.77 |
| Hungary | 16 | 16 | 17 | 18 | –1 | –5.7 | 6.4 | 6.5 | 43.21 |
| Kazakhstan | 1,200 | 1,250 | 1,242 | 1,015 | 227 | 22.3 | 80.0 | 80.0 | 480.00 |
| Romania | 100 | 100 | 99 | 100 | –1 | –1.0 | 17.0 | 18.0 | 105.40 |
| Russia | 9,660 | 9,610 | 9,665 | 9,433 | 232 | 2.5 | 1,700.0 | 1,900.0 | 11,500.00 |
| Other FSU | 500 | 450 | 433 | 517 | –83 | –16.1 | 400.0 | 450.0 | 2,660.00 |
| Other Eastern Europe | 41 | 41 | 46 | 47 | — | –0.5 | 87.8 | 87.7 | 530.99 |
| **Eastern Europe and FSU** | **12,434** | **12,354** | **12,354** | **11,732** | **622** | **5.3** | **2,325.7** | **2,578.3** | **15,507.36** |
| Algeria[1] | 1,370 | 1,360 | 1,343 | 1,355 | –12 | –0.9 | 270.0 | 280.0 | 1,650.00 |
| Angola[1] | 1,639 | 1,689 | 1,644 | 1,381 | 262 | 19.0 | 2.5 | 2.6 | 14.90 |
| Cameroon | 85 | 84 | 84 | 89 | –5 | –6.1 | — | — | — |
| Congo (former Zaire) | 20 | 20 | 20 | 20 | — | — | — | — | — |
| Congo (Brazzaville) | 240 | 240 | 240 | 240 | — | — | — | — | — |
| Egypt | 630 | 630 | 645 | 685 | –40 | –5.8 | 40.0 | 42.0 | 244.60 |
| Equatorial Guinea | 320 | 320 | 320 | 320 | — | — | 0.1 | 0.1 | 0.36 |
| Gabon | 230 | 230 | 230 | 240 | –10 | –4.2 | 0.3 | 0.3 | 1.81 |
| Libya[1] | 1,700 | 1,690 | 1,693 | 1,683 | 10 | 0.6 | 22.4 | 23.0 | 129.90 |
| Nigeria[1] | 2,050 | 2,010 | 2,165 | 2,213 | –48 | –2.2 | 68.0 | 70.0 | 436.00 |
| Sudan | 480 | 480 | 465 | 400 | 65 | 16.3 | — | — | — |
| Tunisia | 108 | 108 | 99 | 65 | 35 | 53.8 | 6.4 | 6.1 | 39.73 |
| Other Africa | 262 | 262 | 262 | 272 | –10 | –3.6 | 9.7 | 10.2 | 59.62 |
| **Africa** | **9,134** | **9,123** | **9,210** | **8,964** | **247** | **2.8** | **419.3** | **434.2** | **2,576.92** |
| Bahrain | 175 | 175 | 172 | 174 | –2 | –1.0 | 24.0 | 25.0 | 145.53 |
| Iran[1] | 3,900 | 3,900 | 3,913 | 3,813 | 100 | 2.6 | 240.0 | 250.0 | 1,495.00 |
| Iraq[1] | 1,930 | 2,000 | 1,952 | 1,857 | 95 | 5.1 | 5.0 | 5.0 | 30.00 |
| Kuwait[1,2] | 2,345 | 2,345 | 2,398 | 2,513 | –114 | –4.5 | 30.0 | 30.0 | 180.00 |
| Oman | 710 | 720 | 718 | 753 | –35 | –4.6 | 55.0 | 57.0 | 335.00 |
| Qatar[1] | 810 | 800 | 800 | 820 | –20 | –2.4 | 110.0 | 110.0 | 655.00 |
| Saudi Arabia[1,2] | 8,485 | 8,565 | 8,490 | 9,254 | –764 | –8.3 | 160.0 | 170.0 | 935.00 |
| Syria | 390 | 390 | 392 | 437 | –45 | –10.3 | 17.4 | 18.0 | 97.30 |
| United Arab Emirates[1] | 2,590 | 2,570 | 2,570 | 2,623 | –53 | –2.0 | 132.0 | 135.0 | 787.00 |
| Yemen | 360 | 360 | 358 | 343 | 15 | 4.4 | — | — | — |
| Other Middle East | — | — | — | — | — | –28.1 | 8.4 | 7.8 | 47.54 |
| **Middle East** | **21,695** | **21,825** | **21,764** | **22,587** | **–824** | **–3.6** | **781.8** | **807.8** | **4,707.38** |
| Australia | 482 | 437 | 453 | 356 | 97 | 27.2 | 129.3 | 115.7 | 680.75 |
| Brunei | 164 | 181 | 182 | 203 | –21 | –10.4 | 33.0 | 27.9 | 204.75 |
| China | 3,836 | 3,791 | 3,775 | 3,702 | 73 | 2.0 | 193.5 | 202.9 | 1,196.57 |
| India | 680 | 668 | 686 | 675 | 11 | 1.6 | 79.3 | 81.0 | 479.18 |
| Indonesia[1] | 830 | 850 | 845 | 918 | –73 | –8.0 | 180.0 | 190.0 | 1,078.00 |
| Japan | 15 | 15 | 17 | 16 | 1 | 7.4 | 9.7 | 9.5 | 65.14 |
| Malaysia | 750 | 740 | 745 | 742 | 3 | 0.4 | 145.0 | 150.0 | 828.00 |
| New Zealand | 22 | 24 | 19 | 16 | 4 | 24.7 | 14.5 | 15.0 | 77.60 |
| Pakistan | 72 | 69 | 67 | 65 | 2 | 2.8 | 116.1 | 120.6 | 699.49 |
| Papua New Guinea | 50 | 50 | 52 | 58 | –6 | –10.9 | 0.5 | 0.5 | 2.95 |
| Thailand | 216 | 212 | 212 | 217 | –6 | –2.6 | 78.8 | 80.0 | 451.92 |
| Vietnam | 300 | 320 | 320 | 347 | –27 | –7.7 | 12.5 | 13.0 | 77.50 |
| Other Asia-Pacific | 35 | 38 | 36 | 32 | 4 | 12.5 | 89.3 | 94.9 | 552.29 |
| **Asia-Pacific** | **7,452** | **7,395** | **7,409** | **7,347** | **62** | **0.8** | **1,081.4** | **1,101.0** | **6,394.13** |
| **TOTAL WORLD** | **71,876** | **72,121** | **72,359** | **72,661** | **–302** | **–0.4** | **7,947.0** | **8,383.0** | **50,664.83** |
| OPEC | 30,019 | 30,149 | 30,217 | 29,668 | 549 | 1.8 | 1,287.4 | 1,335.0 | 7,812.90 |
| North Sea | 3,747 | 4,083 | 4,206 | 4,477 | –272 | –6.1 | 458.3 | 539.6 | 3,572.56 |

[1]OPEC member. [2]Kuwait and Saudi Arabia production each include half of Neutral Zone. Totals may not add due to rounding.
Source: Oil & Gas Journal. Data available in OGJ Online Research Center.

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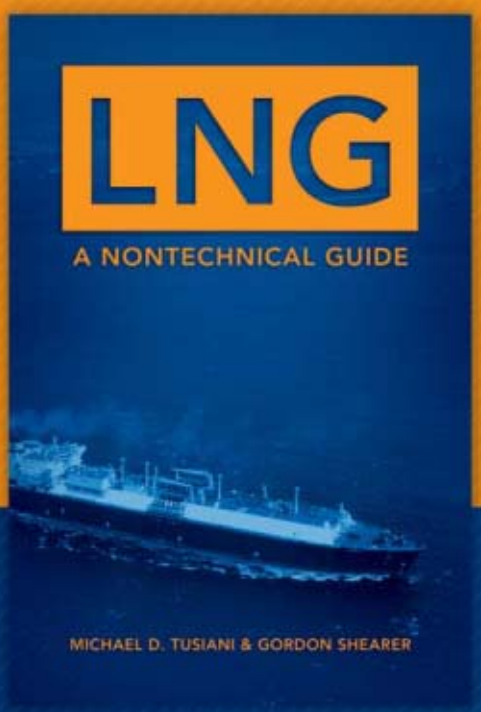


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## Tawdry tricks trample facts in energy politics

*The vicious fraud that masquerades as energy politics is testing limits of acceptability in the US Congress.*

*The Department of Justice's antitrust division and Federal Trade Commission have determined yet again that the oil and gas industry hasn't manipulated gasoline prices.*

*And, yet again, congressional nags won't believe it. In fact, one of them has sprung a devious trap.*

*Justice and FTC on Aug. 30 reported results of a study finding that market forces accounted for increases in the price of gasoline in the late spring and early summer of 2006 (OGJ Online, Aug. 31, 2007).*

*This, said Rep. Bart Stupak (D-Mich.), showed the Bush administration to be concerned only about protecting big oil companies.*

*"The fact remains that last year, when the FTC examined price-gouging under definitions supplied by Congress, the commission found evidence of gouging by refiners and other big oil companies," Stupak said.*

*This "fact" omits much.*

*Here, for example, is the definition of "gouging" to which he refers, which Congress added to a 2006 appropriations bill: "Any finding that the average price of gasoline available for sale to the public in September 2005 [after Hurricane Katrina ravaged Gulf Coast production equipment and refineries], or thereafter in a market area located in an area designated as a state or national disaster area because of Hurricane Katrina, or in any other area where price-gouging complaints have been filed because of Hurricane Katrina with a state consumer protection agency, exceeded the average price of such gasoline in that area for the month of August 2005."*

*Although accompanied by limited exclusions, this definition allows a predictable market response to Hurricane Katrina to be construed as "gouging."*

*So, yes, FTC found in its study of post-Katrina price hikes that, under a perverse definition of the term, "gouging" occurred in 15 instances. But it emphasized that other factors explained the price increases and concluded that no illegal manipulation occurred (OGJ, June 5, 2006, p. 23).*

*Stupak's "fact" omitted that context, too.*

*The omissions show the congressman to be interested less in facts, and therefore in constructive energy policy, than in tawdry political tricks.*

*(Online Aug. 31, 2007; author's e-mail: bobt@ogjonline.com)*

The Editor's Perspective

*by Bob Tippee, Editor*

Market Journal

*by Sam Fletcher, Senior Writer*

## Another hurricane threat

Having just returned to full production after Hurricane Dean, Petroleos Mexicanos again faced a possible decision Sept. 3 whether to evacuate offshore rigs and platforms in the Bay of Campeche as another category 5 storm, Hurricane Felix, churned through the Caribbean.

Felix developed quickly with a much stronger than anticipated pattern, reaching category 5 even before it entered Caribbean waters. Dean also was a category 5 that weakened as it crossed land and entered the Gulf of Mexico. Nevertheless, it forced Pemex to shut down 140 offshore units and move 1,300 workers to land.

At one point, a weather model at the US National Hurricane Center showed Felix possibly passing over the Yucatan Peninsula to enter the Bay of Campeche—where 66% of Pemex's oil production is located—not far from Dean's previous track. "None of the models show it going straight towards the US Gulf but rather through the Yucatan (as did Dean) or Central America," said Olivier Jakob, managing director of Petromatrix GMBH, Zug, Switzerland.

Hurricane Felix later was downgraded to category 4 with sustained winds of 135 mph. Meteorologists said it could fluctuate between the two categories until hitting the mainland. There was no indication Sept. 3 that Pemex was evacuating any workers or shutting down any production as Felix's track appeared to move south toward the Central American coast. Hurricane alerts were issued for Nicaragua, Guatemala, and Belize. However, traders expected Felix to remain a major market force through the rest of the week. They also expected production losses as a result of Hurricane Dean to show up in Sept. 6 reports of US imports.

Oil futures prices rose Sept. 3 in international markets as traders tracked potentially destructive storms that could hit the Gulf of Mexico region. But with US financial markets closed for the Labor Day holiday, trading was sluggish. That holiday marked the end of the US summer driving season, after which gasoline demand historically declines.

### US inventories

The Energy Information Administration reported commercial US crude inventories fell 3.5 million bbl to 333.6 million bbl during the week ended Aug. 24. That surpassed the consensus expectation of a 600,000 bbl draw. US gasoline stocks dropped 3.6 million bbl to 192.6 million bbl in the same period, vs. a consensus draw of 2.5 million bbl; gasoline supply is well below average for this time of year with declines in both finished gasoline and gasoline blending components. Distillate fuel inventories increased 900,000 bbl to 129.9 million bbl, slightly more than the consensus build of 800,000 bbl. US refinery utilization fell to 90.3% during the same week from 91.6% the prior week.

"Gasoline inventories fell by 4.7 million bbl east of the Rockies and hit their lowest absolute level since the 2005 hurricanes," said Paul Horsnell at Barclays Capital Inc., London. "In terms of days of forward cover, they are even tighter than that." US gasoline supplies were then 8.2% below year-ago levels, having fallen 12.1 million bbl in 4 weeks. "The large gasoline draw has left stockpiles at the lowest level since 1991, when the government began collecting this data," said analysts in the Houston office of Raymond James & Associates Inc. However, Jakob at Petromatrix said half of the Aug. 24 draw of crude occurred in "discounted" Petroleum Administration for Defense District 5 (PADD 5) for Hawaii, Alaska, and the West Coast of the continental US. In the other four PADDs, Jakob said, "Overall US crude stocks remain at multi-year highs for the period, both in absolute terms and in days of forward cover but with a balance which remains underweight in PADD 2 [the Midwest] and overweight in PADD 3 [the Gulf Coast]; and this continues to prevent significant pressure to develop on the front West Texas Intermediate time spreads."

### Natural gas outlook

EIA reported the injection of 43 bcf of natural gas into US underground storage during the week ended Aug. 24. That compared with injections of 23 bcf the previous week and 48 bcf during the same period last year. That put total US gas storage at 2.969 tcf, up 71 bcf from year-ago levels and 315 bcf above the 5-year average.

"If we have the same injection each week for the remaining 10 weeks left in storage injection season, inventories would surpass 3.4 tcf in November, which would be close to the record high of 3.461 [tcf] reached on Oct. 20, 2006. It would take injections of 53 bcf to get storage to 3.5 tcf," said analysts at the Société Générale Group in Paris.

(Online Sept. 4, 2007; author's e-mail: samf@ogjonline.com)

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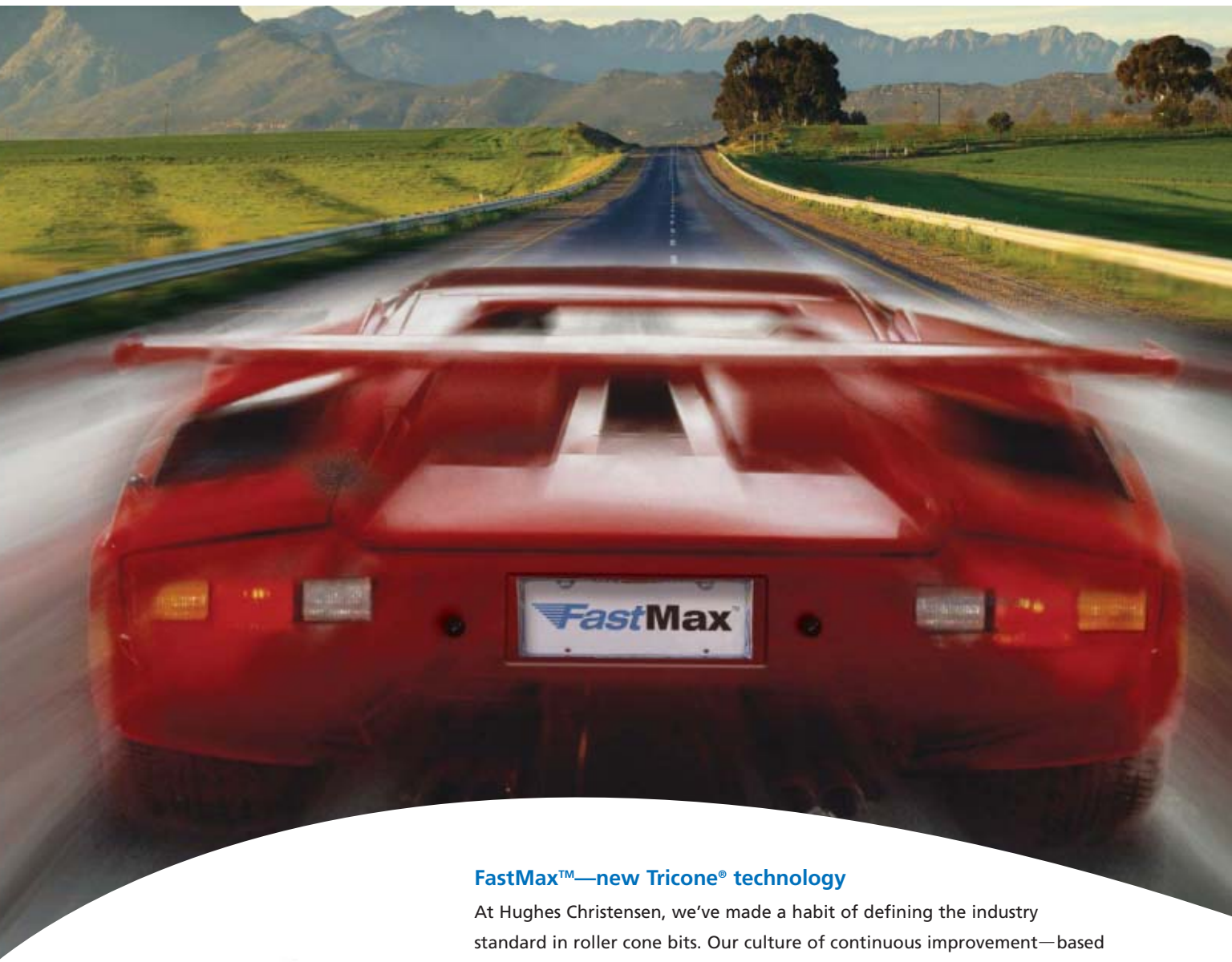


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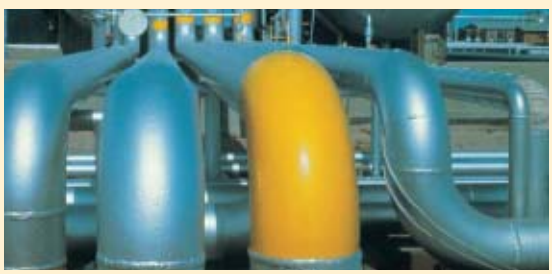

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Bahrain has a prosperous economy based on its key industries of aluminium, oil and gas, metal and ship building and repair, financial services and tourism. Its major trading partners are Saudi Arabia, United States, India, Japan, UK, France, and South Korea.

Having been the first country in the region to discover oil in 1932, Bahrain's economy is now well diversified and the country is less dependent on oil than most other Gulf states. Petroleum production and processing in Bahrain accounts for about 60% of export earnings, 60% of government revenues and 30% of the country's GDP (currently $25,300 per capita). Source: FCO, UK

Bahrain is strategically located at the heart of the key oil and gas markets in the Gulf, in particular Saudi Arabia and Qatar, making it an attractive location to host this inaugural event. With its highly developed communication and transport facilities, Bahrain is home to many multinational companies.

In 2004 Bahrain signed the US-Bahrain Free Trade Agreement, with which the US intends to eliminate certain barriers to trade between the two nations.

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| Wednesday 12 December 2007 | 08:00-17:30 |
| Thursday 13 December 2007 | 08:00-16:00 |

# KEYNOTE SPEAKERS

## H.E. Dr Abdul-Hussain Bin Ali Mirza

**Minister of State and Chairman of National Oil & Gas Authority, Kingdom of Bahrain**

**15:00, Monday 10 December**

H.E. Dr Ali Mirza was appointed Minister of Oil and Gas Affairs in December 2006. His appointment effectively re-established the Ministry which had been replaced by the National Oil and Gas Authority (NOGA) in 2005.

Dr. Mirza is still Chairman of the NOGA and was previously Minister of State (Cabinet Affairs).

## Dr Mustafa Alsayed

**Chief Executive, BAPCO**

Dr Al-Sayed holds a Ph.D. in Industrial Management from the UK, a MSc. in Industrial Management from Ireland and a BSc. in Mechanical Engineering from the UK.

Dr Al-Sayed has worked at BAPCO as Power & Utilities Supervisor for 15 years and prior to that was Chief Engineer at the Ministry of Works, Power and Water, responsible for power generation in Bahrain.

Dr Al-Sayed is currently the President of The Bahrain Petroleum Company B.S.C and is also a Fellow Member of The Bahrain Society of Engineers.

## Mr Amer Al Sulaim

**Executive Director of Industrial Services, Saudi Aramco**

Mr Al-Sulaim holds a B.S. degree in Civil Engineering from KFUPM and an M.S. degree in Construction Management from the University of Washington. He attended the Executives Management Program at Cornell University in 1989.

Mr Al-Sulaim started his career with Saudi Aramco back in 1976. He held several management positions in the areas of Engineering, Inspection, Oil Producing, Pipelines, Project Management, Quality Management, Marine, Mechanical Services, Training and his current position is The Executive Director of Saudi Aramco's Industrial Services organization.

Mr Al-Sulaim is also the Chairman of the Saudi Quality Council. He chaired two international Quality conferences and is very active in change management.

OIL&GAS OGMT MAINTENANCE TECHNOLOGY™

# PRELIMINARY CONFERENCE PROGRAM

## Bahrain International Exhibition Centre

## Monday 10 December

**15:00 – 16:30** **OFFICIAL OPENING OF EXHIBITION AND CONFERENCE**

**H.E. Dr Abdul-Hussain Bin Ali Mirza**
Minister of State and Chairman of National Oil & Gas Authority, Kingdom of Bahrain

**WELCOME KEYNOTES**
**Dr Mustafa Alsayed,** Chief Executive, BAPCO
**Mr Amer Al Sulaim,** Executive Director of Industrial Services, Saudi Aramco

## Tuesday 11 December

09:00 Welcome, Bob Tippee, Editor Oil & Gas Journal, USA

### PREDICTIVE / PREVENTIVE MAINTENANCE AND CASE HISTORY SESSION

**CHAIR: Bob Tippee, Editor Oil & Gas Journal, USA, and Dr Hussain Al-Fadhli, Coating & Metallurgical Specialist, Saudi Aramco, Saudi Arabia**

09:10 **Vibration Analysis and Maintenance Strategies**
Mamdouh B. Al-Aidarous, Saudi Aramco, Saudi Arabia

09:50 **Maintenance & Inspection of Oil Production Tanks in the Kingdom of Bahrain**
Angelito G. Francisco, Bader M. Al Dossary, BAPCO, Bahrain

**10:30** **Refreshment Break**

11:10 **Gas Compressors Instrumentation Trips Analysis**
Abdullah Al-Mugahwy & Ali Rasheed Al-Marri, Saudi Aramco, Saudi Arabia

11:50 **Effect of Black Powder Contaminants on Gas Metering Equipment**
N A Tsochatzidis, Hellenic Gas Transmission System Operator (DESFA) SA, Greece

**12:30 LUNCH HOSTED BY** Bapco

**CHAIR: Mohamed Alqassab, Manager Production Operations, BAPCO, Bahrain**

14:00 **Managing Integrity of PDO Main Oil Lines – Challenges**
Nabeel Ruwaidi, Petroleum Development Oman LCC, Sultanate of Oman

14:40 **16,000 HP Motor Oil Leak; Sharing Best Practice**
Minwer Al-Juhani, Saudi Aramco, Saudi Arabia

**15:10** **Refreshment Break**

15:40 **Fin Fan Belt Tensioner**
Hosam A. Maghribi, Saudi Aramco, Saudi Arabia

16:20 **End of day one**

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# PRELIMINARY CONFERENCE PROGRAM

OIL&GAS OGMT MAINTENANCE TECHNOLOGY™

## Wednesday 12 December

### RELIABILITY AND ASSET MANAGEMENT SESSION

**CHAIR: Yousif Ghuloom, Manager Special Assignment Inspection, BAPCO, Bahrain**

09:00 **Reliability Management – Tools to Improve Asset Reliability**
Dean Fitt, SAP AG, Germany

09:40 **Introducing Apollo Root Cause Analysis to Saudi Aramco Plants**
Hussain H. Al-Abdullah, Faisal I. Al-Jamhoor, Saudi Aramco, Saudi Arabia

**10:20** **Refreshment Break**

11:00 **Development and Implementation of a Reliability Management System in a Refinery**
Atil Gurhan, Ram K Goyal, BAPCO, Bahrain

11:40 **Enhancing the Reliability of Rotating Equipment Shafts by Increasing the Accuracy of Probe Track Reading**
Hussain Al Fadhli, Omer Osman, Saudi Aramco, Saudi Arabia

**12:20 LUNCH HOSTED BY** ارامكو السعودية Saudi Aramco

**CHAIR: Ali K. Al-Ghannam, Maintenance Superintendent, Ras Tanura Refinery, Saudi Aramco, Saudi Arabia**

13:40 **Asset Failure & Repair History**
Zaki M Al Khowaitim, Saudi Aramco, Saudi Arabia

14:20 **Asset Management – Fiction to Facts**
Henk Smith, Rovsing Dynamics
Ruud van Dijk, Neil MacRae, BP, Netherlands

**15:00** **Refreshment Break**

15:30 **The Importance of Asset Performance Management**
Mohammad Khalifa, David Boult, Rayan Hafiz, Sami Sarhan, Saudi Aramco, Saudi Arabia

16:10 **Enterprise Asset Management – Maximizing Return on Assets with an End-to-End Solution**
Matthias Pimiskern, SAP AG, Germany

# PRELIMINARY CONFERENCE PROGRAM

OIL&GAS OGMT MAINTENANCE TECHNOLOGY™

## Thursday 13 December

### MAINTENANCE MANAGEMENT SESSIONS

**CHAIR: Husam Al Dulaim, Maintenance Superintendent, NA/SA Pipelines Department, Saudi Aramco, Saudi Arabia**

09:00 **Work Preparation, Scheduling Execution – Shell "TRilogy" Project**
Larry Olson, Marshall Institute, USA

09:40 **Turnaround Contracting: What can be Effectively Contracted?**
Patrick Voogd, Independent Project Analysis, The Netherlands

**10:20** **Refreshment Break**

11:00 **Computerised Maintenance Management System**
Trinath Sahoo, Indian Oil Corporation Ltd. India

11:40 **Abqaiq Plants Best-In-Class Performance Transformation**
Mohammed A. Al Dossary, Saudi Aramco, Saudi Arabia

**12:20** **LUNCH**

**CHAIR: Lokesh K. Sood, Manager Sulfur Handling Facilities Project (SHF), BAPCO, Bahrain**

13:40 **Maintenance Key Performance Indicators (KPIs)**
Loai Ibrahim, Saudi Aramco, Saudi Arabia

14:20 **Preventive Maintenance Optimization at SAOO**
Ahmad F. Al-Tayyeb, Saudi Aramco, Saudi Arabia

**15:00** **Refreshment Break**

15:30 **Achieving Best-In-Class in Instrumentation**
Fawaz A. Al-Sahan, Saudi Aramco, Saudi Arabia

16:10 **Control and Management of External Corrosion**
Mark Dunham, Metacor Ltd, UK

16:45 **Closing Remarks: Bob Tippee,** Editor, Oil & Gas Journal, USA


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# INFORMATION FOR EXHIBITORS

Oil & Gas Maintenance Technology and Pipeline Rehabilitation & Maintenance are co-hosted by **Saudi Aramco** and **BAPCO** and the combined events offer UNRIVALLED ACCESS to buyers and specifiers in the key national oil companies in the Middle East.

Exhibiting at this forum will provide opportunities to meet key decision makers relating to oil, gas and pipeline maintenance investment programmes throughout the Gulf and further afield throughout the Middle East.

## Exhibiting at OGMT will provide opportunities to:

- Meet strategic decision makers face-to-face
- Build relationships with clients and potential clients
- Raise brand awareness in the market place
- Source new suppliers and business partners

## Other exhibitor benefits:

- Company listing on BOTH event websites
- Listing in the official 2007 Conference Programme – including company contact details and a 30-word description of your company

## Who will attend?

- Senior executive decision makers from international and regional oil and gas companies
- Inspection and maintenance engineers and managers
- Pipeline operators
- Operations managers and supervisors involved in planning and scheduling pipeline transmission
- Coating and corrosion engineers
- Service and equipment suppliers

## What does it cost to exhibit?

**Shell Scheme:** $425 per square metre. Shell scheme includes: white wall panels, fascia board with company name, 1 socket, 3 spotlights, carpet, 1 table, 2 folding chairs, 1 waste paper bin and basic stand cleaning

**Space only:** $350 per square metre

# Enhance your presence at the event

## Sponsorship opportunities

As one of our show sponsors, you'll benefit from increased association with the maintenance industry in the Gulf. Whether your company is already well established in the Middle East or new to the region, we can tailor a unique sponsorship package that meets your event objectives.

## Sponsorship opportunities include:

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## To reserve your exhibit space call your local representative:

Event Director
Frances Webb
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Email: francesw@pennwell.com

Jon Franklin (UAE, UK, Ireland, Scandinavia)
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Email: jfranklin@pennwell.com

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or +44 (0) 7983 388 367
Fax: +44 (0) 1992 656 700
Email: janeb@pennwell.com

Peter Cantu (North America)
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Boost the profile of your brand or company by taking advantage of special advertising rates in the flagship media sponsor titles: Oil & Gas Journal, Oil, Gas & Petrochem Equipment and Offshore magazine. All three titles will benefit from bonus distribution at the event.

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# EXHIBITION FLOOR PLAN

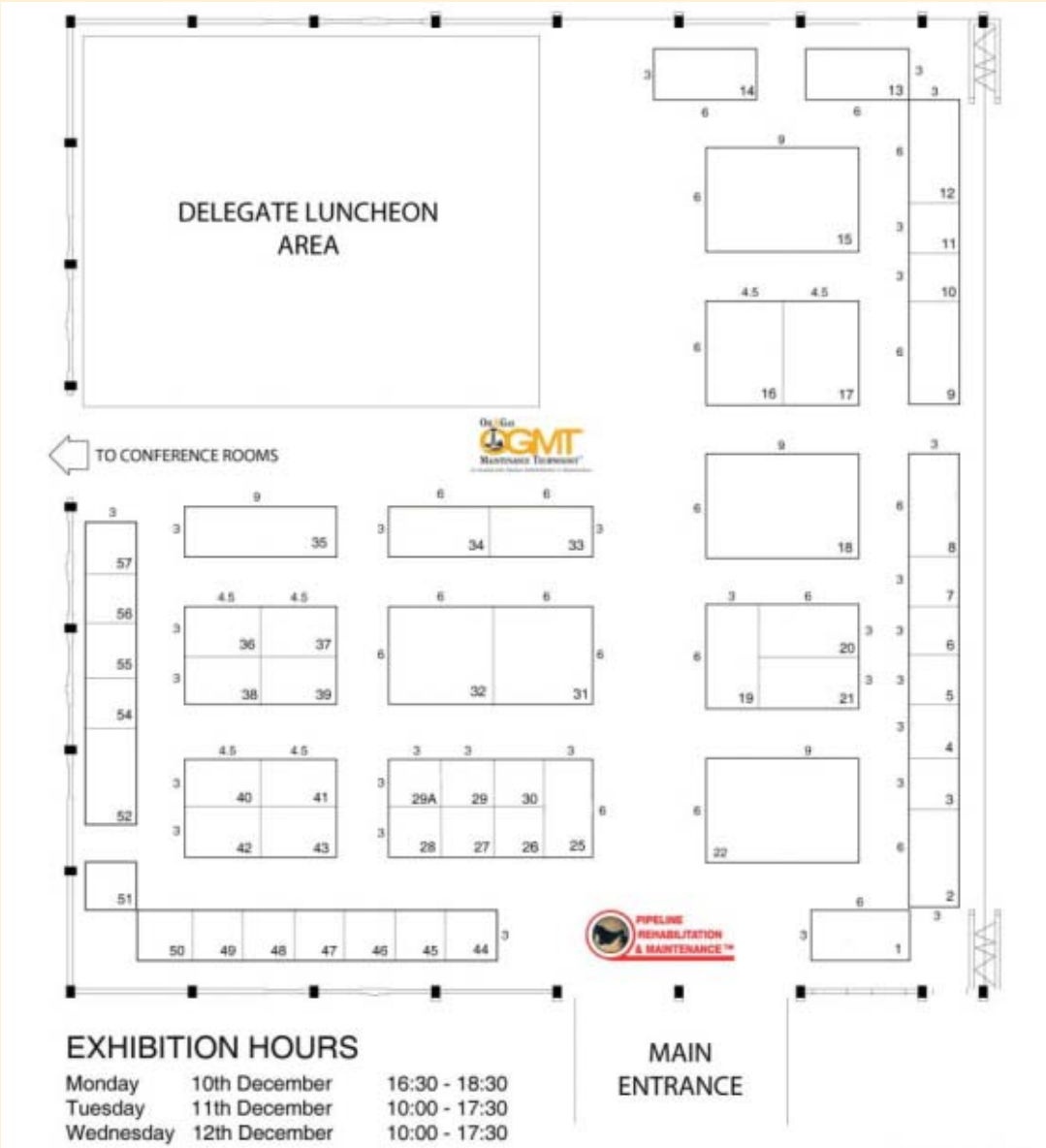
## Exhibitor List*

**Company Name Booth Number**



*List correct as at 23 August 2007

Register free at www.oilandgasmaintenance.com or www.pipeline-rehab.com

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OIL&GAS OGMT MAINTENANCE TECHNOLOGY™

# 2007 Registration Form

9 - 13 December 2007
Bahrain International Exhibition Centre
Manama, Kingdom of Bahrain

PIPELINE REHABILITATION & MAINTENANCE ™

**PLEASE COMPLETE IN BLOCK LETTERS** ☐ MR ☐ MRS ☐ MISS ☐ OTHER

**FIRST NAME**.....

**LAST NAME**.....

**JOB TITLE**.....

**ORGANISATION** .....

**ADDRESS**.....

.....

.....

**COUNTRY**.....

**POSTAL CODE** .....

**TELEPHONE**.....

**TELEFAX** .....

**E-MAIL** .....
confirmations will be sent by email, if a unique email is provided*

**Which conference are you registering for?** OGMT 2007 (Registration code: OGMT07PSGREG) ☐ PRM 2007 (Registration code: PRM07PSGREG) ☐

**1. Type of Company or Organization:**

- ☐ 10 Oil/Gas company
- ☐ 20 Consulting Company
- ☐ 30 Contractor
- ☐ 40 Engineering/Construction
- ☐ 50 Financial
- ☐ 60 Service/Supply
- ☐ 65 Government/Library/Education
- ☐ 70 Other

**2. Job Function:**

- ☐ 02 Management (CEO, Pres.VP)
- ☐ 05 Engineering/Technical/Geoscience
- ☐ 06 Superintendent/Field Professional/Foreman
- ☐ 10 Purchasing/Consulting
- ☐ 12 Other

**3. Areas of Interest/Involvement:**

- ☐ 10 Exploration
- ☐ 01 Production
- ☐ 23 Pipeline/Transportation
- ☐ 15 Refining
- ☐ 39 Financial
- ☐ 05 Drilling
- ☐ 29 Gas Processing
- ☐ 19 Petrochemical
- ☐ 46 Other

**4. Purchasing Role:** ☐ Specify ☐ Recommend ☐ Approve ☐ None

For information on corporate packages for more than 20 attendees contact
Cary Shipley
Phone: + 1 918 832-9220
Email: carys@pennwell.com

**3 ways to register:**
**Pre-register online before 4 December 2007.**
**Register on site after 4 December 2007.**

**1**
**Fax:**
Direct: +1 918 831 9161
Toll-Free (US only): +1 888 299 8057

**2**
**Website:**
www.oilandgasmaintenance.com
www.pipeline-rehab.com

**3**
**Mail:**
PennWell C&E Registration (OGMT/PIPE)
P.O. Box 973059
Dallas, TX 75397-3059 USA

**For questions please call:**
Phone: +1 918 831 9160
Toll Free (US only): +1 888 299 8016

## Conference Fees:

**1. Individual Delegate (Full Conference Registration)***
*Includes:*
- Access to all Conference Sessions
- Access to the Exhibition Hall, (Ticketed)
- Coffee Breaks in Exhibition Hall
- Delegate Lunch on Tuesday, Wednesday and Thursday

☐ Paid By 09 November 2007 $1,375
☐ Paid After 09 November 2007 $1,575

**2. Corporate Plan (Group of 10 Delegates)***
*Includes:*
- Access to all Conference Sessions
- Access to the Exhibition Hall, (Ticketed)
- Coffee Breaks in Exhibition Hall
- Delegate Lunch on Tuesday, Wednesday and Thursday

☐ Paid By 09 November 2007 $10,310
☐ Paid After 09 November 2007 $11,810

**Corporate Plan (Group of 20 Delegates)***
☐ Paid By 09 November 2007 $16,500
☐ Paid After 09 November 2007 $18,900

**3. Pipeline Rehabilitation Workshop Attendee**
- Access to pre-booked Workshop on the corresponding day(s)
- Luncheon on corresponding day(s) (Ticketed)

**Two Day Workshop (Workshops A & B) $1,225**
☐ Workshop A - Introduction to In-line Inspection of Pipelines – 2 days 9th & 10th December
☐ Workshop B – An Updated Look at Pipeline Rehabilitation – 2 days 9th & 10th December

**One Day Workshop (Workshops C) $595**
☐ Workshop C - Reliability & Maintenance of Pipelines Valves and Actuators - 1 day: 9th December

**4. Exhibitor/Delegate (Full Conference Registration)**
- Exhibit booth staff can upgrade their registration to include access to the conference and includes:
- Access to all Conference Sessions
- Access to the Exhibition Hall, including move-in and move-out
- Coffee Breaks in Exhibition Hall
- Delegate Lunch on Tuesday, Wednesday and Thursday (Ticketed)
  - ☐ Paid By 09 November 2007 $1,375
  - ☐ Paid After 09 November 2007 $1,575

**5. Exhibit Floor Only (Dec 10 - 12)** ☐ **Free**

**TOTAL PAYMENT AMOUNT**

Total payment amount in cash
(in US funds only): – US$ _____

Payment must be received prior to conference. If payment in not received by the conference date, the registration fee must be guaranteed on charge card until proof of payment is provided. Make check payable to PennWell/Pipeline Rehab 2006. Cancellation: Cancellation of registration must be received in writing. Any individual, exhibitor or corporate registrations cancelled before 9 November 2007 will receive a 50% refund of registration fee. After 9 November, 2007 no refunds will be permitted. Substitutions may be made at any time by contacting the registration office in writing.

* Your full-price registration fee includes a one-year paid subscription to Oil & Gas Journal (US$ 69.00 value).

**Method of Payment:**

☐ Check enclosed (US$ only) ☐ Wire (Wire information will be provided on invoice)
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PIPELINE REHABILITATION & MAINTENANCE™

# PRELIMINARY CONFERENCE PROGRAM

## Thursday 13 December

### Session 5 – Repairing Pipelines During Rehabilitation

**Chair: Bader Al Dossary, Head Corrosion Engineer, BAPCO, Bahrain**

09:00 **Pipeline Repair Methods and Requirements (Case Study)**
Nadhir I. Al-Nasri, Saudi Aramco, Saudi Arabia

09:40 **Repair Methods of Damaged Steel Pipes Applied in Slovak Transmission Gas Pipeline**
P. Bernasovsk, Welding Research Institute, Slovakia
P. Simko, Slovak Gas Industry, Slovakia

**10:20** **Refreshment Break**

11:00 **Use of SmartPlugs to Isolate Operating Pipelines for Construction and Maintenance Activity**
Mark Sim, TDW Offshore Services AS, Norway

11:40 **Response for Recovering a 28" Gas Pipeline Damaged due to Debris Flow**
Ruben Montano, Petrobras, Bolivia

**12:20** **LUNCH**

### Session 5A – Repairing Pipelines During Rehabilitation (Continued)

13:40 **Predictive Maintenance through Smart Electrical Valve Actuators**
Pablo D. Genta, Saudi Aramco, Saudi Arabia

14:20 **Best Practice in Managing Stress Corrosion Cracking on Gas Pipelines**
Jaime P. Perez, Saudi Aramco, Saudi Arabia

**15:00** **Refreshment Break**

### Session 6 – Rehabilitation Process and Procedures

**Chair: Sid Taylor, President, Incal Pipeline Rehabilitation Inc., USA**

15:30 **The Challenges of Designing and Installing High Pressure Gas Pipelines Through Inshore**
David McGlone, BAPCO
Shallow Waters in Bahrain

16:10 Saudi Aramco Rehabilitation Strategy and Construction Best Practices
Abdullah M. Al- Ghamdi, Rami M. Al-Moaikel, Saudi Aramco, Saudi Arabia

16:50 **Closing Remarks**

17:00 **Close of Conference**

PIPELINE REHABILITATION & MAINTENANCE ™

# PRELIMINARY CONFERENCE PROGRAM

## Wednesday 12 December

### Session 3 - Pipeline Operation Problems

**Chair: Dr Michael Beller, Global Marketing Manager, NDT Systems & Services, Germany**

09:00 **The Hydration Phenomena in the BGT-1 Pipeline**
Misfer Al-Otaibi, Saudi Aramco, Saudi Arabia

09:40 **Effects of Black Powder on Pipeline Integrity and Operations**
Abdelmounam Sherik, Saudi Aramco, Saudi Arabia

**10:20** **Refreshment Break**

11:00 **Application of Integrated Wireless Nano Sensors in Oil Pipeline Integrity Monitoring**
Bonny B. N. Umeadi, School of Architecture & Construction
Dr K. G. Jones, University of Greenwich, UK

11:40 **Forecasting Failure Models for Pipelines through Neutron Diffraction-Based Stress Assessment Tools**
Pablo Genta, Saudi Aramco, Saudi Arabia
Massimo Rogante, Rogante Engineering Office, NDT, Italy

**12:20 LUNCH HOSTED BY** ارامكو السعودية Saudi Aramco

### Session 4 - Cleaning and Coating of Pipelines During Rehabilitation

**Chair: MuhammadAli Trabulsi, General Manager, Pipelines Dept., Saudi Aramco, Saudi Arabia**

13:40 **Rehabilitating Large Diameter Gas and Oil Pipelines in a Plant Installation**
Igor Alexeevich Kramarenko, Kubangazificatia, Russia
Irina Koroleva, Incal Pipeline Rehabilitation, Inc., Germany

14:20 **Pipeline Debris, Short Term and Long Term Solutions**
Laurence Abney, Halliburton AS, Norway
Allan Browne, Halliburton, UK

**15:00** **Refreshment Break**

15:30 **Application of In-Situ Coating for Internal Carbon Steel Pipelines in Saudi Aramco**
Bakr. S. Hammad, Saudi Aramco, Saudi Arabia

16:10 **MAIN OIL LINES (MOLs) COATING REHABILITATION Selection of Coating System to Enhance MOLs Integrity**
Ali Mohamed El Kordi, Abu Dhabi Company for Onshore
Mahmoud El Al fy, Oil Operations (ADCO)
Ibrahim Washash, United Arab Emirates

# PRELIMINARY CONFERENCE PROGRAM

**Bahrain International Exhibition Centre**
**Tuesday 11 December 2007**

PIPELINE REHABILITATION & MAINTENANCE ™

**16:30 - 16:30** OFFICIAL OPENING OF EXHIBITION AND CONFERENCE

**H.E. Dr Abdul-Hussain Bin Ali Mirza**
Minister of State and Chairman of National Oil & Gas Authority, Kingdom of Bahrain

**WELCOME KEYNOTES**
**Dr Mustafa Alsayed,** Chief Executive, BAPCO
**Mr Amer Al Sulaim,** Executive Director of Industrial Services, Saudi Aramco

## Tuesday 11 December

### Session 1 - Managing Pipeline Integrity

**Chair: Warren True, Chief Technology Editor - LNG/Gas Processing, Oil & Gas Journal, USA**

09:00 **LNG/Gas Processing, Oil & Gas Journal, USA**
Warren True, Chief Technology Editor

09:10 **Inspection of Existing Pipeline Systems Including Upgrade to State-of-the-Art**
Markus Rieder, ILF Consulting Engineers, Germany

09:50 **Identification, Quantification and Defect Identification, Quantification and Defect**
Fernando Vicente, Eduardo Risso, ABB Full Service®, Argentina

**10:30** **Refreshment Break**

11:10 **Total Pipeline Integrity Management System- PETRONAS Gas Berhad's World Class Practices**
Mohd Nazmi bin Mohd Ali Napiah, Mohd Nazir bin Mohd, Nor PETRONAS Gas Berhad, Malaysia

11:50 **Managing Integrity of PDO Main Oil Lines - Challenges**
Nabeel Ruwaidi, PDO, Oman

**12:30 LUNCH HOSTED BY** Bapco

### Session 2 - Evaluating Pipeline Integrity

**Chair: Dr Konrad Reber, TÜV Rheinland Industrie Service GmbH, Germany**

14:00 **Benchmarking on Pipeline Integrity Management System - A PETRONAS Gas Berhad's Experience**
Mohd Nazmi bin Mohd Ali Napiah, Md Aidi bin Rais, PETRONAS Gas Berhad, Malaysia

14:40 **Metal Loss Defect Assessment in Heated Pipeline: A RPA-LLC Methodology Case Study**
E.S.M. Nicoletti, A.G. Souza, Petrobras Transporte S.A., Brazil

**15:10** **Refreshment Break**

15:40 **"See through the Earth Technology" for Pipeline Integrity Inspection**
Svetlana Kamaeva, Transkor-K, Russia
Paul Jarram, Hitech Engineering Materials and Systems Ltd, UK

16:20 **New Multi-Technology In-Line Inspection Tool for the Quantitative Wall Thickness Measurement of Gas Pipelines**
A. Barbian, NDT Systems & Services AG
M. Beller, Stutensee, Germany
H. Willems, F. Niese, Fraunhofer Gesellschaft, Germany

11:50 **End of Day One**

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# KEYNOTE SPEAKERS

## H.E. Dr Abdul-Hussain Bin Ali Mirza

**Minister of State and Chairman of National Oil & Gas Authority, Kingdom of Bahrain**

15:00, Monday 10 December

H.E. Dr Ali Mirza was appointed Minister of Oil and Gas Affairs in December 2006. His appointment effectively re-established the Ministry which had been replaced by the National Oil and Gas Authority (NOGA) in 2005.

Dr. Mirza is still Chairman of the NOGA and was previously Minister of State (Cabinet Affairs).

## Dr Mustafa Alsayed

**Chief Executive, BAPCO**

Dr Al-Sayed holds a Ph.D. in Industrial Management from the UK, a MSc. in Industrial Management from Ireland and a BSc. In Mechanical Engineering from the UK.

Dr Al-Sayed has worked at BAPCO as Power & Utilities Supervisor for 15 years and prior to that was Chief Engineer at the Ministry of Works, Power and Water, responsible for power generation in Bahrain.

Dr Al-Sayed is currently the President of The Bahrain Petroleum Company B.S.C and is also a Fellow Member of The Bahrain Society of Engineers.

## Mr Amer Al Sulaim

**Executive Director of Industrial Services, Saudi Aramco**

Mr Al-Sulaim holds a B.S. degree in Civil Engineering from KFUPM and an M.S. degree in Construction Management from the University of Washington. He attended the Executives Management Program at Cornell University in 1989.

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# PIPELINE REHABILITATION & MAINTENANCE PRE-CONFERENCE WORKSHOPS

PIPELINE REHABILITATION & MAINTENANCE ™

9-10 DECEMBER 2007

## Workshop B: An Updated Look at Pipeline Rehabilitation

A two-day intensive course on current pipeline rehabilitation techniques being used around the world. The course features in-depth coverage of the engineering aspects of in-situ pipeline rehabilitation including topics such as working over operating pipelines, raising and lowering operating pipelines and determining safe operating parameters for reconditioning operating pipelines. Case studies of pipeline rehabilitation projects from around the world are presented and analyzed. Draft procedures for performing field pipeline rehabilitation are included in the course materials. Ten popular pipeline coating systems are compared based on physical and application properties. A model for determining total applied costs of a coating allows the student to develop a cost comparison of the coatings for a specific project. In-plant rehabilitation of old pipelines is discussed including inspection methods to determine fitness for re-use.

### ABOUT THE AUTHOR

**Sid Taylor** is the president of Incal Pipeline Rehabilitation, Inc., and has over 30 years' experience in the design and development of automated high-pressure water jet cleaning and coating systems. Sid has been awarded numerous U.S. and foreign patents for inventions in pipeline coating removal, surface preparation and coating application, has written and presented over 45 technical papers on pipeline rehabilitation, many of which have been published by leading industry journals.

## Workshop C: Maintenance of Pipelines Valves and Actuators

**Valve Reliability**

- Application
- Service Conditions
- Type of Valves
- Functionalities
- Materials
- Standards Overview
- Selection Methods
- Valve Reliability- Case Study
- Open Discussion

**Actuator Reliability**

- Application
- Service Conditions
- Type of actuators
- Functionalities
- Materials
- Standards overview
- Selection methods
- Actuator reliability-case study
- Open discussion

**Valve-Actuator Sizing**

- Standards
- Challenges in proper sizing
- Cost-Effective sizing
- Safety Considerations
- Operability and maintainability
- Case-study
- Open discussion

**Valve Maintenance**

- Valve Maintenance - Case study
- Valve in-line maintenance
- Preventive maintenance
- Open Discussion

**Actuator Maintenance**

- Preventive maintenance for Gas Operated Actuators
- Predictive maintenance for Motor Operated actuators
- Obsolescence criteria
- Maintenance optimization

### ABOUT THE AUTHOR

**Essam Al-Arfaj** is a Pipeline Engineer with experience in valve and actuators engineering design, maintenance and operations. Mr Al-Arfaj graduated in Mechanical Engineering, specialized in Industrial Applications of valves and actuators, and has worked in Saudi Aramco Pipelines Maintenance and Engineering Departments. He has been involved in the valve actuator market since 1995, covering different positions then. Today he is working with Pipelines Specialist Unit as Valve Specialist.

**Pablo Genta** is an Instrumentation and Control Engineer with experience in design, start-up and operations of control systems in gas treatment plants, and pipelines facilities in Middle East and the Americas. After obtaining his MS Degree in Electrical Engineering, Mr. Genta worked in process automation in the manufacturing industry. Since 1994 he worked for various engineering companies in oil & gas projects. He has published articles and papers on pipelines technologies, safety protection systems (ASSE) and solar energy technologies (WRENC). In 2003 Mr. Genta joined Saudi Aramco with the Pipelines Department as Instrumentation and Control engineer.

### SUMMARY


**Target Group:**
Pipeline engineers, technicians and other personnel from pipeline operators and the oil and gas industries that deal with maintenance and operation of pipeline valves and actuators. Engineering consultants, inspectors and integrity assessment personnel from certification authorities involved with pipeline inspection and assessment.

**Aim:**
This workshop will provide an introduction into maintenance and reliability aspects of pipelines valve and actuator through the presentations and analysis of case-studies taken from Saudi Aramco facilities. The delegate will be able to get acquainted of numerous applications of valves and actuators in the vast Saudi Aramco pipeline network. The lecturers will introduce the challenges that operators and maintenance personnel face with the different valve and actuator technologies and how preventive and predictive maintenance help optimizing the maintenance job. This workshop will also provide an overview of various sizing techniques for valve and actuators and the importance of proper sizing to achieve reliability. This workshop is intended to develop in an interactive manner between lecturers and audience facilitating the exchange of experiences and discussion of the case studies presented. Photographs and engineering details are also provided.


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PIPELINE REHABILITATION & MAINTENANCE ™

# PIPELINE REHABILITATION & MAINTENANCE PRE-CONFERENCE WORKSHOPS

THE DIPLOMAT RADISSON SAS HOTEL & SPA, MANAMA, BAHRAIN 9-10 DECEMBER 2007

## Workshop A: Introduction to In-Line Inspection of Pipelines

### Level: In-Depth Introduction

### Course Content

**1. Introduction**

**2. Flaws and Defects in Pipelines**
- 2.1 Pipeline materials
- 2.2 Types of pipelines
- 2.3 Geometric Anomalies
- 2.4 Metal Loss
- 2.5 Cracks and Crack-Like Defects
- 2.6 Leaks
- 2.7 Failure Modes

**3. Pipeline Inspection**
- 3.1 Hydro- and Stress testing
- 3.2 In-line Inspection
- 3.3 External Inspection

**4. Non-Destructive Testing and In-Line Inspection**
- 4.1 Metal Loss Survey Tools
- 4.1.1 Magnetic Flux Leakage Tools
- 4.1.2 Ultrasound Tools
- 4.2 Ultrasound Technology
- 4.3 Inertia or Mapping Tools
- 4.4 Caliper Tools
- 4.5 Crack Detection Tools

**5. In-Line inspection Tools**
- 5.1 Overview of tools (pictures)
- 5.2 Overview of vendors

**6. Pipeline Inspection Procedures**
- 6.1 Planning an inspection
- 6.2 The Technical Questionnaire
- 6.3 Preparing the Pipeline for an Inspection
- 6.4 Tool Traps
- 6.5 Pipeline Cleaning
- 6.6 Pipeline Gauging
- 6.7 Performing the Inspection
- 6.7.1 Batching
- 6.7.2 Tracking
- 6.7.3 Safety
- 6.7.4 Launching, Receiving etc.
- 6.7.5 Data Check

**7. Reporting**
- 7.1 Data Evaluation
- 7.2 Sample Report
- 7.3 Feature Localization
- 7.4 Feature List
- 7.5.Final Report: What do you get
- 7.6 Verifications

**8. Integrity Assessment**
- 8.1 Assessment of metal loss Defects
- 8.2 Crack Assessment
- 8.3 Run Comparisons
- 8.4 Corrosion Growth reports and estimated lifetime

## LITERATURE

### Exercises

**The course also includes a workshop session and exercises covering the following topics:**

Which Tool Does What?
How to read Tool Data and Defect Specification Sheets
Preparing an Inspection Project
Data Analysis and MAOP

### Lecturers:

Dr Michael Beller
NDT Systems & Services AG
Am Hasenbiel 6
76297 Stutensee
Germany

Dr Konrad Reber
TÜV Rheinland
Industrie Service GmbH
Am Grauen Stein
51105 Köln
Germany

**Aim:** The course will provide an in-depth introduction into the subject of the in-line inspection of pipelines. The delegate will learn which part in-line inspection plays in the overall pipeline inspection and pipeline maintenance procedures. The course will introduce the flaws and anomalies observed in pipelines. In-Line inspection tools and the various physical principles they use will be covered in depth.

The material covers details on a pipeline inspection operation, including pipeline preparation, cleaning, gauging.

Final Reports, Reporting Formats are discussed. The course also includes an introduction into data analysis, integrity assessment and run comparisons. Special emphasis is placed on using data obtained from in-line inspection tools.

**Target Group:** Pipeline Engineers, technicians or other interested personnel from operators. Engineering consultants active in the field of NDT and Integrity Assessment. Personnel from the authorities or certification bodies involved with pipeline inspection and assessment.
**Duration: 2 days**

# INFORMATION FOR EXHIBITORS

Oil & Gas Maintenance Technology and Pipeline Rehabilitation & Maintenance are co-hosted by **Saudi Aramco** and **BAPCO** and the combined events offer UNRIVALLED ACCESS to buyers and specifiers in the key national oil companies in the Middle East. Exhibiting at this forum will provide opportunities to meet key decision makers relating to oil, gas and pipeline maintenance investment programmes throughout the Gulf and further afield throughout the Middle East.

## Exhibiting at Pipeline Rehabilitation & Maintenance will provide opportunities to:

- Meet strategic decision makers face-to-face
- Build relationships with clients and potential clients
- Raise brand awareness in the market place
- Source new suppliers and business partners

## Other exhibitor benefits:

- Company listing on BOTH event websites
- Listing in the official 2007 Conference Programme – including company contact details and a 30-word description of your company

## Who will attend?

- Senior executive decision makers from international and regional oil and gas companies
- Inspection and maintenance engineers and managers
- Pipeline operators
- Operations managers and supervisors involved in planning and scheduling pipeline transmission
- Coating and corrosion engineers
- Service and equipment suppliers

## What does it cost to exhibit?

**Shell scheme:** $425 per square metre. Shell scheme includes: white wall panels, fascia board with company name, 1 socket, 3 spotlights, carpet, 1 table, 2 folding chairs, 1 waste paper bin and basic stand cleaning

**Space only:** $350 per square metre

# Enhance your presence at the event

## Sponsorship opportunities

As one of our show sponsors, you'll benefit from increased association with the maintenance industry in the Gulf. Whether your company is already well established in the Middle East or new to the region, we can tailor a unique sponsorship package that meets your event objectives.

## Sponsorship opportunities include:

- Conference Delegate packs
- Welcome Reception
- Luncheon
- Tea and Coffee Breaks

## To reserve your exhibit space call your local representative:

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Frances Webb
Phone: +44 (0) 1628 810 562
Fax: +44 (0) 1628 810 762
Email: francesw@pennwell.com

Jon Franklin (UAE, UK, Ireland, Scandinavia)
Phone: +44 (0) 1992 656 658
or +44 (0) 7985 229 324
Fax: +44 (0) 1992 656 700
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Email: janeb@pennwell.com

Peter Cantu (North America)
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www.pipeline-rehab.com

# INFORMATION FOR VISITORS

## About Bahrain

Bahrain has a prosperous economy based on its key industries of aluminium, oil and gas, metal and ship building and repair, financial services and tourism. Its major trading partners are Saudi Arabia, United States, India, Japan, UK, France, and South Korea.

Having been the first country in the region to discover oil in 1932, Bahrain's economy is now well diversified and the country is less dependent on oil than most other Gulf states. Petroleum production and processing in Bahrain accounts for about 60% of export earnings, 60% of government revenues and 30% of the country's GDP (currently $25,300 per capita). Source: FCO, UK

Bahrain is strategically located at the heart of the key oil and gas markets in the Gulf, in particular Saudi Arabia and Qatar, making it an ideal location to host the 9th annual Pipeline Rehabilitation & Maintenance conference and exhibition. With its highly developed communication and transport facilities, Bahrain is home to many multinational companies.

In 2004 Bahrain signed the US-Bahrain Free Trade Agreement, with which the US intends to eliminate certain barriers to trade between the two nations.

## Who should attend Pipeline Rehabilitation & Maintenance?

- Senior executive decision makers from international and regional oil and gas companies
- Pipeline inspection and maintenance engineers and managers
- Pipeline operators
- Operations managers and supervisors involved in planning and scheduling pipeline transmission
- Coating and corrosion engineers
- Service and equipment suppliers

## HOTEL INFORMATION

The Diplomat Radisson SAS Hotel & Spa
BD 88 Single / BD 93 Double

InterContinental Bahrain
BD 60 Single / BD 68 Double

Crowne Plaza Bahrain
BD 60 Single / BD 68 Double

*Rates subject to availability and only available via www.pipeline-rehab.com*

## EXHIBITION OPENING HOURS

Monday 10 December 2007
16:30 - 18:30

Tuesday 11 December 2007
10:00 - 17:30

Wednesday 12 December 2007
10:00 - 17:30

## HOW DO I REGISTER?

- Register FREE for the exhibition at www.pipeline-rehab.com
- Register yourself and your colleagues as conference delegates by 9 November and benefit from a $200 EARLY BIRD DISCOUNT
- Either register online at www.pipeline-rehab.com, mail or fax back the form on page 10 to +1 918 831 9161

**This registration is valid for Pipeline Rehabilitation & Maintenance and Oil & Gas Maintenance Technology**

## ON-SITE REGISTRATION HOURS

| | |
|---|---|
| Workshop Only: Sunday 9 December 2007 | 07:30-17:00 |
| Monday 10 December 2007 | 14:00-18:00 |
| Tuesday 11 December 2007 | 07:30-17:30 |
| Wednesday 12 December 2007 | 08:00-17:30 |
| Thursday 13 December 2007 | 08:00-16:00 |

# PIPELINE REHABILITATION & MAINTENANCE ™

**Bahrain International Exhibition Centre**
**Manama, Kingdom of Bahrain**
**9–13 December 2007**

www.pipeline-rehab.com

## Welcome to Pipeline Rehabilitation & Maintenance Technology Conference and Exhibition

Current high oil and gas commodity prices make oil spills and vapor escapes from operating pipelines more costly than ever before. At the same time, public and governmental pressures on pipeline operators to protect air, water, and ground environments have never been greater.

The convergence of these factors heightens the need for pipeline operators to share experiences in monitoring and controlling system flows and diagnosing and rehabilitating lapses in line integrity. As Middle East producers and processors ramp up their operations to meet greater hydrocarbon energy demand, this conference stands as an established and leading forum in bringing together operating and service companies and their technical and management personnel to learn the latest and best in pipeline rehabilitation and maintenance.

The previous eight conferences have firmly established the value and need for an international specialised meeting to examine issues centered on the fitness for purpose question of oil and natural gas transmission lines.

**Frances Webb**
Event Director
PennWell Petroleum Group

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# PIPELINE REHABILITATION & MAINTENANCE ™

Bahrain International Exhibition Centre
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