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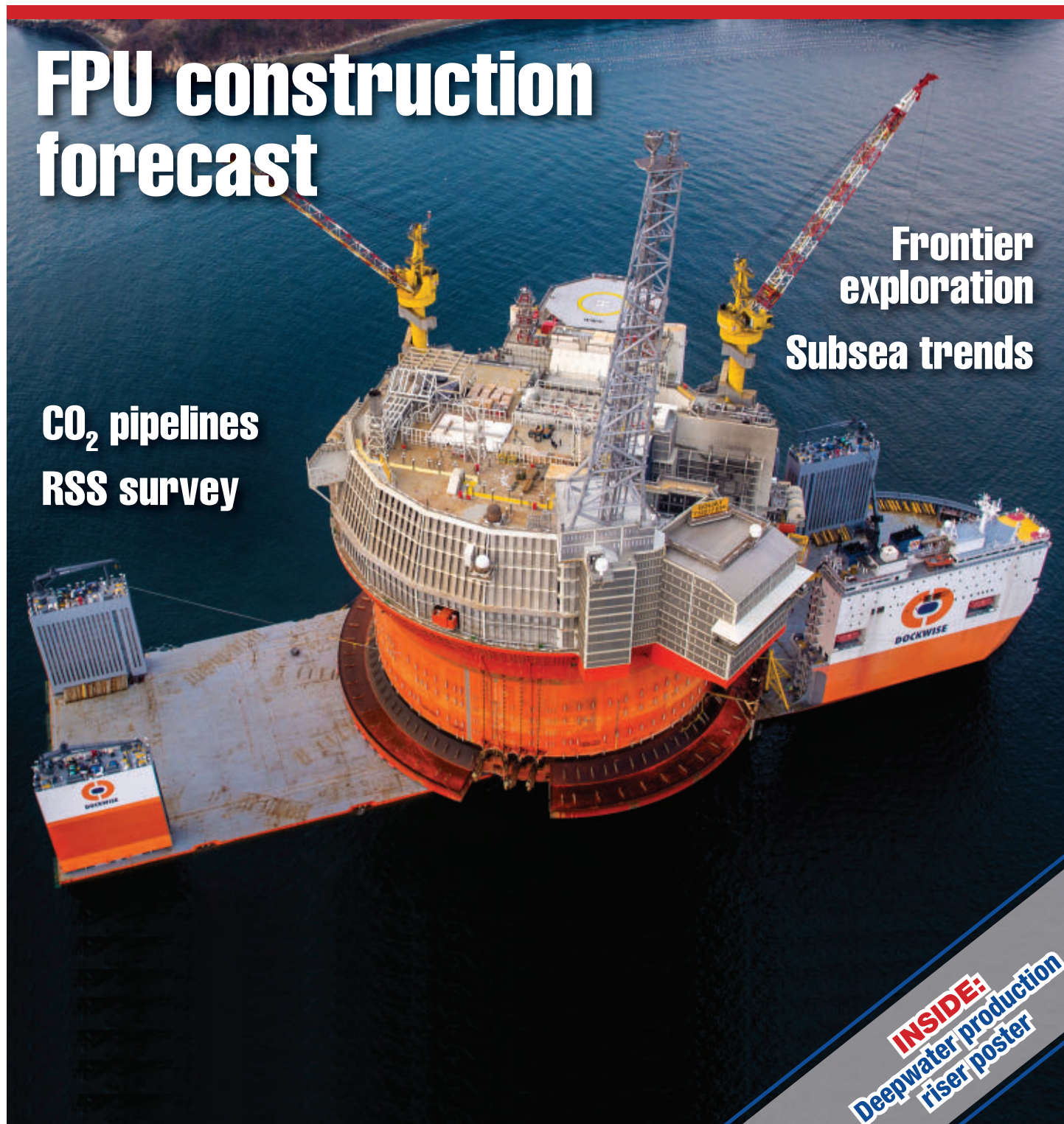
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Deepwater production
riser poster



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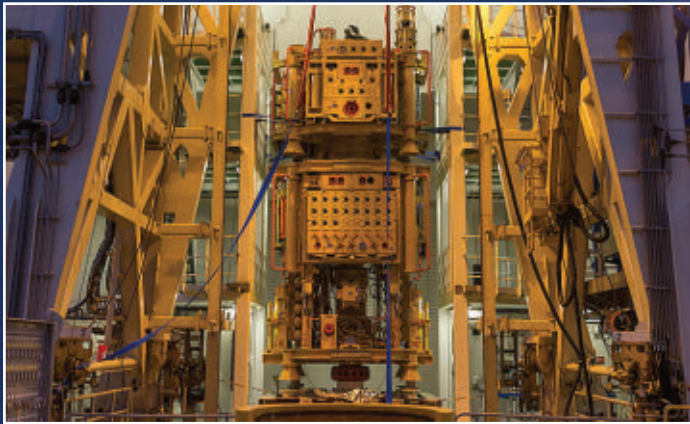
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FRONTIER EXPLORATION

Governments advance emerging plays in Eastern Mediterranean, North Atlantic 36

Basins in the eastern Mediterranean Sea are of increasing interest following the discovery of deepwater gas offshore Israel. However, some of the newly-licensed areas could be more prospective for oil, according to presentations at IRN's Oil & Gas International Licensing Summit in London earlier this year.

INDUSTRY INTERVIEW

Joint venture combines parents' services to offer fresh approach to consulting 42

In January, McDermott International and GE Oil and Gas formed io oil & gas consulting, a joint venture that looks to offer a holistic approach in developing front-end solutions for offshore fields. The London-based venture, which plans to expand into the US and Asia, says it will approach the full-field development as one system. *Offshore* recently met with io CEO Dan Jackson to discuss the company's goals, opportunities, and industry trends.

AFRICA

Opportunities still beckon for investors of all sizes offshore Africa 46

Operators off West Africa should revise their goals to suit changing market conditions, according to speakers at the Institute of Petroleum's recent IP Week 2015 conference in London. Ramin Lakani, Halliburton's regional general manager, said there was an improved climate of political stability across the region.

GEOLOGY & GEOPHYSICS

Barbados invites bids for offshore blocks 48

Barbados' government will open large parts of the country's offshore area for bidding during 2015, with favorable terms for international oil companies. All these unlicensed blocks can be considered as a rank wildcat exploration area, and early movers will be able to pick up the best prospects. Mapping of the region's Cretaceous La Luna age-equivalent source rock – not previously feasible using the old seismic – is now possible, and the new data has led to identification of more than 20 large oil prospects.

3D CSEM can play vital role in offshore exploration 52

3D controlled source electromagnetic (CSEM) surveys map resistive bodies in the subsurface – fluid-driven parameters that correlate strongly with the fluid content and saturation of hydrocarbons where the larger the resistive body, the greater the response. Whereas most prospects generally have higher uncertainty in probability of success to start with based on seismic interpretation alone, adding EM data will enable better fluid predictions. When trying to optimize and prioritize a portfolio of prospects, 3D CSEM data provides operators with the ability to polarize their portfolio and identify areas with larger hydrocarbon accumulations where they are more likely to be economically viable.



DRILLING & COMPLETION

Real-time measurements, data management enhance operational efficiency 56

A better solution to protect high-value investments in offshore and subsea installations is to take a proactive approach, using real-time downhole, subsea, and surface measurements to monitor and analyze well performance. This enables operators to curtail performance deterioration and deter imminent failure of downhole artificial lift equipment, as well as to tailor preemptive responses to potentially unsafe conditions such as hydrate, asphaltene, or wax precipitation.

Feasibility study assesses two dry tree options for the Gulf of Mexico 60

Operators in the Gulf of Mexico (GoM) are increasingly looking to ultra-deepwater (>5,000-ft/1,524-m water depth) fields and more challenging reservoirs to deliver the hydrocarbons that the energy market demands and to satisfy their production growth objectives. DNV GL was granted an award by the Research Partnership to Secure Energy for America, partially funded by the US Department of Energy's National Energy Technology Laboratory, to manage a project to develop dry tree semi concepts for the ultra-deepwater fields in the GoM.

Advances in rotary steerable systems improve efficiency 66

The first patents for so-called steerable systems were issued in the late 1800s, and applied primarily in water wells. A full century passed before modern rotary steerable systems (RSS) made their oilfield debut, reportedly on BP's Wytch Farm extended-reach play. Today, with depressed oil and gas prices, operators are primarily concerned with cost reduction. *Offshore* asked four RSS providers for an update on their latest efforts to improve drilling efficiency and add value.

2015 Rotary steerable systems directory 70

Get the latest detailed and comprehensive listing of rotary steerable systems available on the market.



the heart of the matter



78



ENGINEERING, CONSTRUCTION, & INSTALLATION

Red Hawk stands as first spar ever decommissioned in GoM 78

The Red Hawk spar made history throughout its design life, commissioned and decommissioned as the first of a kind. Heralded as the first cell spar ever built, it remains the lone cell spar ever fabricated just slightly 10 years after its inception. Decommissioned in September 2014, it then earned distinction of being the deepest floating production unit retired in the Gulf of Mexico.

Deepwater construction vessel provides improved stability, novel pipelay 82

In February, the two main cranes and vertical lay system were fitted on Ceona's new deepwater field development vessel *Ceona Amazon* at the Huisman yard in Schiedam, the Netherlands. The 199.4-m (654-ft) long vessel, which will be the flagship of Ceona's growing fleet, is designed to perform in multiple pipelay and operational modes, including heavy lift and subsea construction.

Lewek Constellation heads to the Gulf of Mexico 86

EMAS AMC has introduced the *Lewek Constellation*, a unique vessel that finds itself in an increasingly unique situation. By the time it hits the waters of the Gulf of Mexico in April, the subsea construction vessel will have a backlog of work worth more than \$500 million with a \$120-million West African job already completed. At nearly 180 m (591 ft) long, *Lewek Constellation* is a DP-3 ice-classed, multi-lay offshore construction vessel with ultra-deepwater pipelay and heavy-lift capabilities.

Industry advances deepwater production riser technology 88

This issue of *Offshore* magazine includes an update to the Deepwater Production Riser Systems & Components Poster. Nearly five years have passed since the last edition of this poster was published, and there have been several advances related to riser technology over this short period of time.

PRODUCTION OPERATIONS

Emerging markets to drive FPU construction over near term 90

Through the end of the decade, the largest markets for floating production systems are expected to remain Brazil, West Africa, and Southeast Asia. However, there are new areas of growth, particularly in East Africa and the Mexican portion of the Gulf of Mexico. The fastest growing segment is forecast to be gas processing units, namely FLNGs and FSRUs, which are expected to account for 25% of all floating production systems capital expenditures over the next five years.

Sevan adapts circular floaters for future regasification, FLNG needs 96

Sevan Marine is developing new applications for its cylindrical floater technology. To date, the Arendal, Norway-based contractor has designed and supplied floaters for use as FPSOs, drilling rigs and accommodation units. More recently, its focus has been on concepts for floating storage and offloading units; gas-handling operations such as FLNG and floating storage and regasification; and studies for power plants and carbon capture.

Digital oilfield offers new model for production optimization 100

Remote monitoring solutions help oil and gas producers visualize their operations with real-time, comprehensive data that is easily transformed into actionable information to help achieve goals of reduced downtime and increased productivity. Through cloud computing, these solutions are not only applied quicker, but also are more easily scalable as other transformative technologies emerge in the future.

Dual compact flotation unit delivers big gains in oil removal efficiency 104

Schlumberger's EPCON division in Porsgrunn, Norway, has redesigned its compact flotation unit (CFU) technology. The resultant EPCON Dual CFU, the company claims, offers major improvements in separation and treatment of produced water on fixed and floating installations. The original EPCON team began working on the CFU concept in the late 1990s, with the first offshore installation completed on a Norsk Hydro's Troll C platform in the Norwegian sector in 2001.

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International Edition
Volume 75, Number 4
April 2015



COVER: The Goliat cylindrical FPSO platform has started its voyage from South Korea to Norway on board the *Dockwise Vanguard*, the world's largest heavy lift vessel. The Goliat project is now entering the final stage of its development phase prior to coming on stream this summer. Goliat will be the first oil field to come onstream in the Barents Sea, and is the world's most northerly offshore development. The platform is operated by Eni Norge and is the largest and most sophisticated cylindrical floating, production, storage and offloading (FPSO) facility ever built. For more on this platform design, see the article by contributing editor Nick Terdre on **page 96**. (Photo courtesy Seven Marine ASA)

SUBSEA

Subsea processing moves forward with challenges in tow 106

New technology has been implemented gradually both in greenfield developments and modifications of existing fields, but for many of the technologies that adaptation is still low. There are several key subsea technology developments in the works that could reduce future barriers for widespread use. Subsea processing is the concept of gradually moving the entire topsides processing facilities to the seabed which would create better financial returns due to increased recovery.

PIPELINES & FLOWLINES

Offshore industry examines integrity of CO₂ pipelines 110

With energy security and climate change at the top of the global agenda, climate change mitigation technologies such as carbon capture, utilization and storage (CCUS) are gaining momentum. The number of offshore CO₂ pipelines is therefore expected to grow significantly in the future. CCUS technology offers a solution for both supporting production of incremental hydrocarbon reserves from existing fields while at the same time storing CO₂ away from the atmosphere, avoiding climate impacts.

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Offshore ISSN-0030-0608



Printed in the U.S.A. GST No. 126813153

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New on demand webcast

► Standardization of Offshore Production Systems

Aimed at reducing cost and schedule of its projects, Petrobras decided to promote the standardization of its offshore production systems. Based on a radical change in design philosophy, standards units have been designed and proved to be applicable to a wide range of crudes. This strategy has been successful. Projects are reaching shorter schedules with higher local content. This success led to a contract of eight similar units in Brazil, for use in presalt deepwater areas. By acquiring standard equipment and modules, the company has effectively promoted competitiveness, cost reduction, and reduced schedules in its supply chain.

Giovani Cavalcanti Nunes, corporate manager - Process Technologies, Petrobras, presents the EPC strategy and an update on the construction of the eight units as well as an overview of future opportunities.

<http://www.offshore-mag.com/webcasts/offshore/2015/03/standardization-of-offshore-production-systems.html>

New videos

► Jack/St. Malo

Chevron presents three videos describing the development of the deepwater Jack/St. Malo project in the Gulf of Mexico. The Jack and St. Malo fields are within 25 mi (40 km) of each other in about 7,000 ft (2,100 m) of water in the Walker Ridge area, approximately 280 mi (450 km) south of New Orleans. The fields were co-developed with subsea completions flowing back to a single host, semisubmersible floating production unit located between the fields. Production began in December 2014.

<http://www.offshore-mag.com/topics/video-index>

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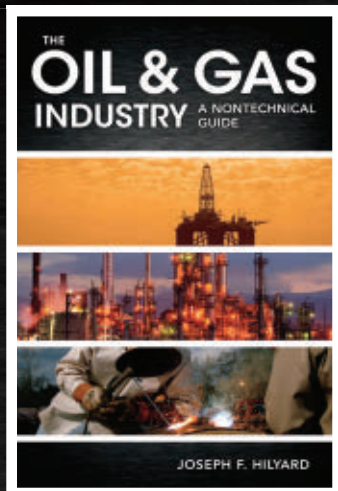


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David Paganie • Houston

New operator mix emerging in West Africa

As IOCs in West Africa and the Gulf of Guinea region continue divesting non-core assets and shifting resources to deepwater and elsewhere, new opportunities are emerging for local, home-grown investors.

In Nigeria, the number of indigenous operators has swelled to about 50, and those companies now control 30% of domestic crude oil reserves and 10% of the production. Nigeria's regulatory authority, Department of Petroleum Resources (DPR), attributes the inception of this trend to a number of government-sponsored initiatives, beginning with the introduction of the Indigenous Operator Program in 1990. This program awarded 30 blocks, mainly onshore. Currently, independents hold about 10.5 Bboe of oil and 45 tcf of natural gas in 76 blocks (659 fields) and 30 marginal fields. Most of the fields are conventional assets (onshore and shallow water), where the technical and financial constraints are considerably less than in deepwater. DPR estimates the upside for the independents at 20 Bboe from about 900 prospects and leads.

One downside is the strain on regulatory resources available to handle increasing pressure from the independents, which are demanding more fiscal incentives and better operating conditions. These trends were discussed by DPR executives at the Offshore West Africa (OWA) Conference & Exhibition this past January in Lagos, Nigeria. The regulatory agency contends that an association, such as IPAA in the US or BRINDEX in the UK, would help facilitate public and private sector collaboration and compliance with regulations.

Another barrier for indigenous growth is access to capital, due largely to increasing competition from the influx of independents. Equity markets have been a major source of funding for Africa-focused E&P firms. Two Nigerian independents, Oando and Seplat, have been raising capital on local and international stock markets to fund expansion plans. Oando's listing on the Toronto Exchange helped it raise the capital to acquire ConocoPhillips' upstream Nigerian interests for \$1.5 billion, the largest transaction to date for any African independent E&P company. The assets include interests in two deepwater blocks.

Meanwhile, a similar growth in indigenous operators is occurring in Africa's second largest oil producer – Angola – but perhaps not yet to the extent seen in Nigeria.

Still, the IOCs remain the largest investor group in the region, despite recent asset divestitures and the impending Petroleum Industry Bill (first proposed in 2008) in Nigeria. Some regional stakeholders believe that the bill could reduce the economic feasibility of select deepwater projects. As the IOCs possess the technical expertise for deepwater development, it would seem that attracting a healthy mix of investor types would be the best way forward.

For more on the investment outlook in Africa, see the comprehensive review by Offshore Europe-Editor Jeremy Beckman on **page 36**.

Offshore production outlook

Regional oil production is shifting from onshore and shallow water areas to deepwater, and natural gas from offshore is expected to figure more prominently in the resource mix.

Speaking at OWA in January, Rolake Akinkugbe, Head of Energy and Natural Resources for FBN Capital, estimated that new production from 33 offshore fields in West Africa and Gulf of Guinea could lift regional oil output from a 2015 year-end figure of 6.8 MMb/d to 8 MMb/d by 2020. But, some \$40 billion of capital will be needed to reach this production level, she added.

Offshore oil production has grown to about 70% of the region's total, with more than 80% of it off Nigeria and Angola. Offshore natural gas from the region could figure into the mix in 2019 from independent Ophir Energy's FLNG project offshore Equatorial Guinea. Project FID is expected in 2017. West Africa is estimated to hold 32% of Africa's natural gas reserves.

In the whole of Africa, deepwater oil comprises about 20% of the continent's production and it could rise to 27% by 2025, according to recent market analysis by McKinsey & Company. Production from deepwater natural gas will rise considerably when the projects off East Africa come online.

Clearly, there are opportunities in West Africa for all types of investors. It will be interesting to watch how the outcome of the elections in Nigeria and other geopolitical trends along the coast will impact investor opportunities and confidence in the region.

David Paganie

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2014 Sept	\$151,000	\$499,516	\$735,000
2014 Oct	\$151,000	\$504,797	\$735,000
2014 Nov	\$151,000	\$509,522	\$735,000
2014 Dec	\$151,000	\$507,827	\$735,000
2015 Jan	\$151,000	\$503,464	\$735,000
2015 Feb	\$151,000	\$508,798	\$735,000
Jackup			
2014 Mar	\$30,000	\$130,141	\$361,000
2014 Apr	\$30,000	\$130,934	\$361,000
2014 May	\$30,000	\$132,237	\$365,000
2014 June	\$30,000	\$135,269	\$365,000
2014 July	\$30,000	\$135,450	\$365,000
2014 Aug	\$30,000	\$138,065	\$389,000
2014 Sept	\$30,000	\$140,862	\$389,000
2014 Oct	\$30,000	\$142,490	\$389,000
2014 Nov	\$30,000	\$143,009	\$389,000
2014 Dec	\$30,000	\$144,002	\$389,000
2015 Jan	\$30,000	\$144,831	\$389,000
2015 Feb	\$30,000	\$145,621	\$389,000
Semi			
2014 Mar	\$145,000	\$382,254	\$643,000
2014 Apr	\$145,000	\$387,243	\$643,000
2014 May	\$145,000	\$390,355	\$643,000
2014 June	\$145,000	\$393,113	\$643,000
2014 July	\$145,000	\$394,413	\$643,000
2014 Aug	\$145,000	\$391,988	\$641,000
2014 Sept	\$145,000	\$386,702	\$641,000
2014 Oct	\$145,000	\$388,760	\$641,000
2014 Nov	\$145,000	\$392,191	\$641,000
2014 Dec	\$145,000	\$390,367	\$641,000
2015 Jan	\$145,000	\$398,081	\$641,000
2015 Feb	\$145,000	\$398,125	\$641,000

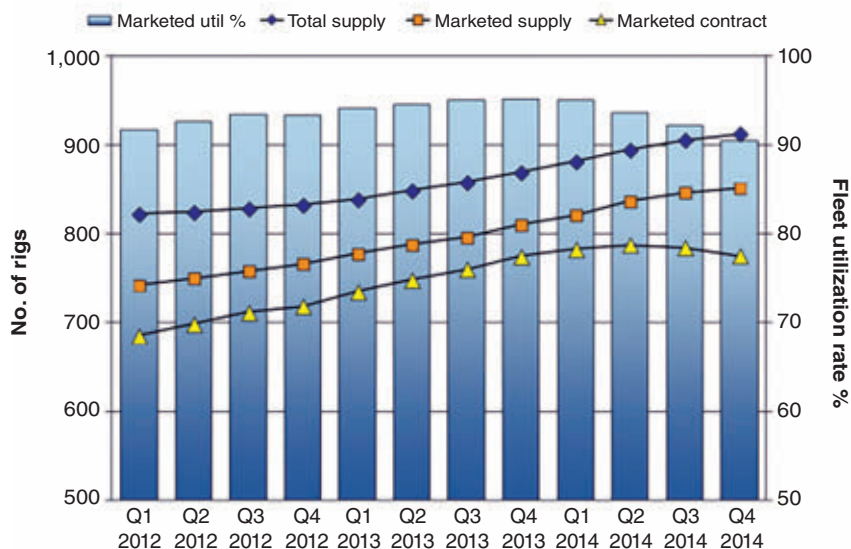
Source: Rigzone.com

This month Infield Systems looks at frontier exploration with a particular focus on developments in Africa. East Africa is emerging as an important hydrocarbon province, with recent years seeing an increase in exploration activities in deep and ultra-deepwaters offshore Mozambique and Tanzania. Eni and Anadarko have made major discoveries in the Rovuma basin in Mozambique such as the Mamba Complex in Area 4 and Prosperidade and Golfinho-Atum prospects in Area 1. Offshore Tanzania, BG Group and Statoil have made significant discoveries such as the Jodari prospect in block 1 and the Piri prospect in block 2. Both countries are likely to capitalize on their large natural gas resources for indigenous use and by building LNG export infrastructure, with key demand markets likely to be in Asia.

While East Africa has the potential to become an important industrial player, the established West African region is also seeing frontier exploration centered on

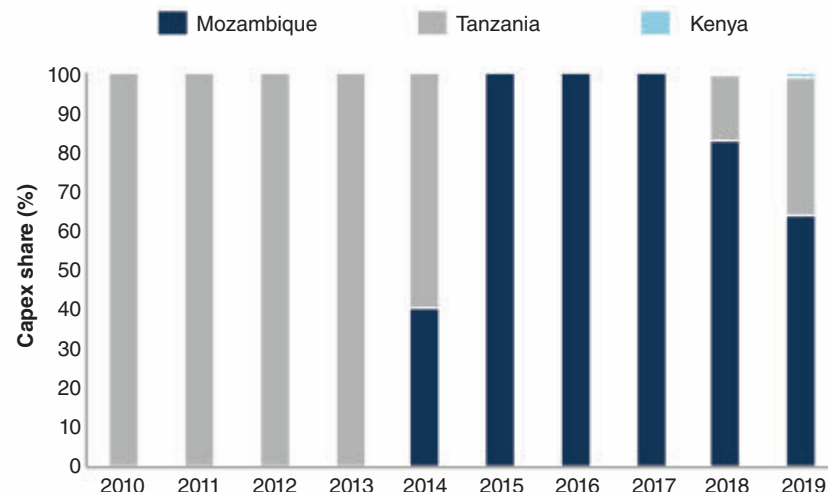
Worldwide offshore rig count & utilization rate

Quarterly average 2012-present



Source: IHS Petrodata RigBase

East African offshore capex share (%) by country



Source: Infield Systems' Market Modeling & Forecasting Database

its presalt plays. The prospect of emulating the successes of Brazil makes West African presalt plays attractive. Presalt discoveries have already been made in Angola, Congo and Gabon, while under-explored Namibia is also a potential candidate for future discoveries; however no commercial presalt discoveries in the country have yet been brought into production.

The fall in global oil prices has created challenges for the offshore oil and gas industry, with frontier exploration likely to be adversely affected. Exploration in frontier areas can involve the use of advanced technologies deployed in sometimes challenging environments, increasing the cost and risk of exploration and development. With E&P companies re-evaluating their budgets and portfolios, high-risk and high-cost developments, such as developments in the Arctic, could face delays.

—George Griffiths, Senior Energy Researcher, Infield Systems

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Short-term FPSO outlook strong

Investments in floating production systems worldwide are set to soar to \$21 billion in 2017, up from \$12 billion this year, according to Douglas-Westwood's latest market forecast. However, both figures apply mainly to commissioned facilities - the outlook for new orders looks poor, the analysts claimed, with the oil price decline likely to delay sanction of various new projects.

FPSOs comprise the largest segment of the market between 2015-2019, accounting for 87 installations and 81% of the forecast capex, followed by TLPs and other floating production systems. Almost one-third of the forecast installations are for Latin America, with 68% of the facilities globally destined for deepwater projects.

The Bahamas

A second reading of a new Petroleum Act was due to go before the Bahamian parliament this winter, and following a consultation phase the proposals should pass via the senate into law. Bahamas Petroleum Co., which has completed studies for a drilling campaign offshore the Bahamas, says it remains committed to spudding its first well as soon as possible.

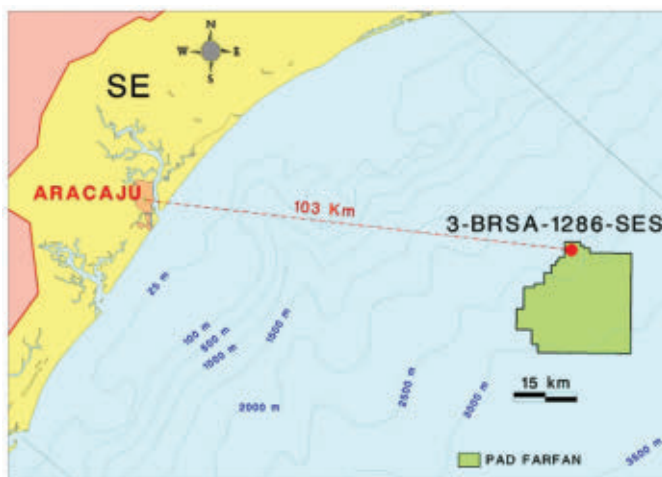
South America

Tullow Oil plans to acquire 4,000 sq km (1,544 sq mi) of 3D seismic over block 54 offshore Suriname. This summer, the company expects to participate in a well operated by Teikoku Oil on the Spari prospect in offshore block 31.

...

Statoil and Sinochem have submitted a Phase 2 development plan for the Peregrino oil field offshore Brazil. This calls for installation of a second wellhead platform (Platform C) which will be used to drill 15 oil producers and six water injectors on the southwest part of the field from a new drilling center installed in 120 m (393 ft) of water. The platform will be connected to the *Peregrino* FPSO and will also supply power to the existing wellhead platform. Statoil expects the \$3.5-billion scheme to recover a further 250 MMboe.

...



Farfan extension in Sergipe basin offshore Brazil. (Map courtesy Petrobras)

Petrobras has confirmed an extension of an oil and gas discovery in the Farfan area of Brazil's Sergipe-Alagoas basin, 103 km (64 mi) from Aracaju. The well, drilled in 2,467 m (8,094 ft) of water, 10 km (6.2 mi) from the discovery well, also penetrated a shallower-lying, 68-m (223-ft) thick light oil accumulation.

Elsewhere off Brazil, the company proved heavy oil with a well on

the ultra-deepwater Basilisco structure in the Campos basin, 143 km (89 mi) from Armação dos Búzios on the Rio de Janeiro state coast.

...

The semisubmersible *Eirik Raude* was due to sail into Stanley harbor at the end of February to prepare for a six-well exploration campaign on various licenses offshore the Falkland Islands. Rockhopper will participate in four wells, all in the North Falkland basin (NFB), with the first likely to be on the Zebedee prospect.

Rockhopper's partner Premier Oil is assessing design options for a leased FPSO for its planned first-phase development of the Sea Lion oil field in the NFB. This would be connected to a single subsea drill center. The company is currently targeting sanction for this phase during 1Q 2016, and hopes to bring in a partner to co-fund this and subsequent phases that could involve more FPSOs or a TLP.

West Africa

Kosmos Energy has agreed to farm out to Chevron 30% of its interest in three contiguous concessions offshore Mauritania. Water depths over blocks C8, C12, and C13 range from 5,249-9,842 ft (1,600-3,000 m). Assuming approval from the government for the transaction, Kosmos would remain operator in the exploration phase with Chevron assuming control in the event of a commercial discovery.

Tullow has agreed to transfer a 40.5% stake in Mauritania's shallow-water block C-3 to Sterling Energy for around \$2.5 million, in consideration for past costs. Tullow is due to process 1,600 km (994 mi) of newly acquired 2D seismic over the block, fulfilling its Phase 1 commitments. If the partners opt to enter the next two phases, the obligations include 3D seismic and two wells. Sterling sees this as an emerging shelf play, following Cairn Energy's 2014 SNE-1 oil discovery off Senegal to the south.

...

Offshore Cameroon, Sterling is hoping for government approval to assume Murphy's 50% operated interest in the Ntem concession, where water depths vary from 400-2,000 m (1,312-6,562 ft). Last year the partners drilled the unsuccessful Bamboo-1 well on the concession, which is in the prospective southern Douala/Rio Muni basin.

...

Eni has a new gas/condensate discovery offshore Gabon. The Nyone Deep 1 well was drilled in block D4. Eni assessed in-placed resources at around 500 MMboe.

Mediterranean Sea

PA Resources (PAR) has canceled a proposed sale of operating interests to EnQuest in the Didon oil field and the Zarat permit offshore Tunisia. This follows the failure of the Tunisian authorities to issue a letter of non-objection to the transaction. PAR says it is continuing studies on Zarat, the country's largest unexploited gas discovery, and aims to submit a development plan later this year.

...

Subsidiaries of Israeli conglomerate Delek Group have accepted a request from Cyprus' government for an extension to negotiations on gas imports via pipelines from the deepwater Leviathan field offshore Israel. The period of validity now runs until April 30. Noble Energy operates Leviathan in the Levantine basin offshore Israel.

Black Sea/Caspian Sea

The semisub *Ocean Endeavour* has been drilling the Pelican South-1 exploration well in the Romanian sector of the Black Sea for ExxonMobil and partner OMV Petrom. Earlier, the rig completed an appraisal well on the Domino gas discovery. The partners plan additional drilling to evaluate the deepwater Neptun block's potential.

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North Caspian Operating Co. has contracted Saipem for further pipelay for the shallow-water Kashagan field in the Kazakh sector of the Caspian Sea. Under the \$1.8-billion program, Saipem will install two 95-km (59-mi), 28-in. carbon steel pipelines, internally clad with a corrosion alloy layer, connecting the offshore D island with the onshore plant at Karabatan. The offshore sections of the lines will be around 65 km (40 mi) long. Work is expected to be completed by the end of 2016.

Production at Kashagan had to be suspended soon after start-up in late 2013 following stress cracking in the pipeline system caused by hydrogen sulfide (H₂S) in the field's wellstream.

Middle East

The heavy-lift barge *Lan Jing* has installed the Hasbah tie-in platform (TP) for Saudi Aramco offshore Saudi Arabia. The vessel's 7,500-ton crane lifted a weight of around 5,000 tons, a new record for an Aramco heavy-lift operation.

Additionally, the vessel installed the 4,600-ton Arabiyah field tie-in platform and a 1,800-ton intermediate injection platform. The Arabiyah-Hasbah gas fields project is designed to supply 2.5 bcf/d to the onshore gas plant at Wasit.

...

Iran Offshore Oil Co.'s new 2.2-MMbbl floating storage unit/export terminal has started operating in the Persian Gulf. It is designed to receive and store 200,000 b/d of produced crude from the offshore Norouz and Soroush fields. News service Shana claimed the double-hulled FSU is the largest of its type in the world, at 337 m (1,105 ft) long, 60 m (197 ft) wide, and 33 m (108 ft) high.

East Africa

Anadarko proved gas from two reservoirs with its latest appraisal well on the deepwater Orca discovery in Mozambique's Offshore Area 1. It has since drilled a further well on the 2014 Tubarão Tigre gas discovery. The Area 1 partners continue to negotiate long-term gas sales from their various fields which they plan to develop via LNG. They currently have heads of agreement in place to supply more than 8 MM metric tons/yr (8.8 MM tons/yr), Anadarko said.

...

A 3D seismic survey was due to start last month over the Ambilobe block offshore Madagascar, operated by Sterling Energy. The company and partner Pura Vida recently won an extension to the production-sharing contract until July 2016.

India/Southeast Asia

Technip has completed the floatover installation of the 8,200-metric ton (9,039-ton) integrated production deck for the HRD process platform at ONGC's Heera field offshore western India. The contractor's Indian office designed the topsides for the Unideck method, which allows installation of large decks in a single operation in long-period swells via a series of jacks that lower the topsides into place.

...

South Korean company SK has secured operatorship of two blocks in the Pearl River Mouth basin in the South China Sea. Blocks 04/20 and 17/03 are in water depths of 50-100 m (164-328 ft). The company and partner CNOOC will acquire 2D seismic and drill exploration wells.

In the offshore Bohai region, CNOOC has produced first oil from its Jinzhou 9-3 field adjustment project in the North Liao Bay, where



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water depths vary from 6.5-10.5 m (21.3-34.5 ft). Main facilities are a central processing platform, a wellhead platform, and 21 production wells. Later this year, output should reach a peak of 12,000 b/d.

...

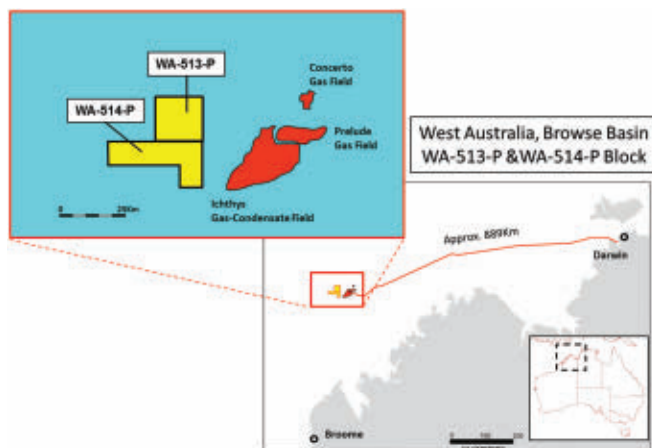
Myanmar's government has awarded Shell operatorship of deep-water blocks AD-9, AD-11, and MD-5 under the country's 2013 off-shore bidding round. Shell has a 90% interest in each case, in partnership with Mitsui.

...

Talisman Energy is working on a development for the CRD oil and gas discovery in block 07/03 offshore Vietnam. According to partner Pan Pacific Petroleum, the favored concept is a tension leg wellhead platform and an FPSO, with first oil potentially in 2018.

Australasia

Santos and INPEX have been awarded two exploration permits off northwest Australia, 500 km (310 mi) northeast of Broome, in water depths of 300-400 m (984-1,312 ft). Release Areas WA-513-P and WA-514-P are close to large gas discoveries that include the INPEX-operated Ichthys field, Shell's Prelude, and last year's Lasefer find.



Santos and INPEX were awarded two new blocks in the Browse basin. (Map courtesy INPEX)

INPEX hopes to prove more gas to supply the Ichthys LNG project. In February, the *ENSCO-5006* started drilling the first of 20 production wells in the Brewster reservoir. The wells will be grouped around five drill centers.

...

Woodside Petroleum has contracted Wood Group Kenny to perform front-end engineering and design (FEED) of a 16-in. corrosion-resistant alloy subsea flowline system. This will serve the proposed Greater Western Flank Phase 2 (GWF-2) development for the North West Shelf project offshore Western Australia. GWF-2 will harness gas from the Dockrell, Lady Nora, Keast, Rankin, and Sculptor accumulations. An investment decision is due later this year.

...

Test results from two wells at the Kupe oil and gas field 30 km (18.6 mi) south of New Zealand's Taranaki coast look promising, according to partner New Zealand Oil & Gas. Operator Origin Energy commissioned fluid contact measurements and additional perforations below existing perforations to enhance production. Analysis suggests ultimate recovery may be higher than previously forecast and that untapped gas reserves may lie trapped beneath shale layers. ●



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Costs drive Oseberg platform plans

Statoil and its partners are considering an unmanned, remotely controlled platform for the next development phase of the Oseberg field in the North Sea. Although the concept is established in the Danish and Dutch sectors, it would be a first for Norway.



Schematic of unmanned platform for Oseberg. (Courtesy Statoil)

The installation, which would have no living quarters, helideck or lifeboat, would be managed from the Oseberg field center. Statoil said the conventional alternative of a subsea tieback would have cost more when factoring in construction, drilling, equipment, and maintenance. The company plans to use service vessels to perform maintenance linked to the platform via gangways after development drilling has been completed. The partners will take a final decision on the Oseberg Future development Phase 1 next winter.

Earlier this year production started from Oseberg Delta 2, another of Statoil's fast-track subsea projects which Norway's parliament sanctioned in late 2013. This is a further development on the Delta terrace where two wells have produced oil from a subsea template since 2008. The new facilities, comprising two templates with slots for eight wells, are 14 km (8.7 mi) south of Oseberg. Statoil estimates the cost of the project at around \$920 million, below the figure at the time the project was approved. The initial phase calls for three oil and two gas producer wells, and the partners plan exploration drilling targeting further reserves in the southern part of the terrace.

Goliat platform sails to Barents Sea

The Sevan Marine-designed cylindrical Goliat FPSO left the Hyundai Heavy Industries yard in South Korea in February onboard the *Dockwise Vanguard*, and is due to reach Hammerfest in northern Norway in mid-April. There the platform is due to make a brief stop before beginning the tow-out to the Eni-operated Goliat field in the Barents Sea. Tie-in operations and preparations for production will follow, and Eni predicts a mid-year start-up. The facility will

be the northernmost oil production center in the Norwegian sector to date, and will be supplied with electrical power directly from the mainland via what is claimed to be the world's longest submarine cable of its type.

Shell preparing for first Brent removal

Shell was due to finish a 30-day public consultation last month on its plans to decommission the first of the four giant platforms serving the Brent oil and gas field in the UK northern North Sea. Since coming onstream in 1976, the field has produced around 10% of all UK North Sea oil and gas production, the company claims. However, Shell has been preparing for cessation of activity for some time, with the Brent D platform shutting down for good in 2011, followed last November by Brent Alpha and Bravo. Only Brent Charlie remains in operation.

Brent D is the first installation scheduled for removal. Shell plans to use Allseas' new giant heavy-lift/decommissioning vessel *Pioneering Spirit* (ex-*Pieter Schelte*) this summer to withdraw the platform's 23,500-metric ton (25,904-ton) topsides in one piece. It has made preparations to strengthen the topsides in anticipation of the lift, which would be one of the heaviest in the North Sea to date. Shell says the single-lift operation offers advantages including lessened risk, cost, and environmental impact. Assuming approval from the UK government, the removed structure would be towed to Able UK's decommissioning yard on England's northeast coast.

Trio to examine concrete mattress removal options

Decom North Sea has formed an initiative with Zero Waste Scotland and subsea engineering group Jee to develop new solutions for recovery and subsequent re-use of concrete subsea mattresses in the North Sea. The mattresses protect pipelines, cables, and umbilicals against dropped objects, also providing added weight and stabilization.



Mattress recovery operation offshore. (Photo courtesy Decom North Sea)

However, they were not designed to be removed and can degrade underwater over time. Jee is investigating efficient, lower-cost removal methods that would allow the mattress materials to be retained for productive use elsewhere. Additionally, the company will develop guidance on best practice for recovery and on derogation cases that require leaving the facilities in situ on the seafloor.

North Sea deal in doubt

Britain's government has reportedly blocked a deal by LetterOne to purchase RWE Dea's UK North Sea interests. The Russian oil company, which recently appointed ex-BP CEO John Browne to spearhead expansion overseas, had agreed to a deal with Germany's RWE to acquire its Dea division for \$5.6 billion. However, the Department of Energy & Climate Change was said to view the arrangement as contravening European and US sanctions against Russia because of its policy toward Ukraine.

Providence agrees to farm-in for Barryroe

In the southern Irish sector, Providence Resources says it has agreed on commercial terms with a potential partner on a farm-in to the Barryroe oil field in the North Celtic Sea basin. Providence has been looking to develop the field in which it has an 80% operated stake. Additionally, it has agreed to acquire Chrysaor's Irish E&P subsidiary, a partner to Providence in the Spanish Point gas/condensate field off western Ireland.

UK operating costs reach new high

Oil & Gas UK expects Britain's offshore oil and gas output to increase this year to 1.43 MMboe/d, as up to 15 new fields enter production. However, forward UK activity continues to suffer from the lower oil price and higher operating costs, which soared last year to a new high of \$28.56/boe.

At the same time, total revenues fell to just over \$37 billion, the lowest for the sector since 1998, resulting in a negative cash flow for the basin of \$8.18 billion. This is the worst result, the association says, since the early days of North Sea investments in the 1970s.

Capex on sanctioned UK offshore projects looks set to drop to around \$14.6-17.4 billion this year, the association adds, potentially tailing off to just \$3.86 billion by 2018. The outlook for reserves replacement too remains bleak. Only 14 exploration and appraisal wells out of the anticipated 25 were drilled in UK waters last year, and the association forecasts no more than eight to 13 this year as explorers continue to struggle to attract capital for drilling. ●

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Oil production in federal GoM expected to keep increasing

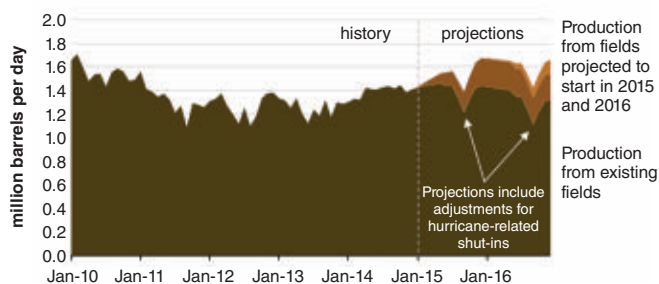
Crude oil production in the federal Gulf of Mexico is expected to continue to rise over the next two years, according to a recent report issued by the US Energy Information Administration (EIA).

Because of the long timelines associated with Gulf of Mexico (GoM) projects, the recent downturn in oil prices is expected to have minimal direct impact on GoM crude oil production through 2016, the report states.

EIA projects GoM production to reach 1.52 MMb/d in 2015 and 1.61 MMb/d in 2016, or about 16% and 17% of total US crude oil production in those two years, respectively.

The forecasted production growth will be driven both by new projects and the redevelopment and expansion of older producing fields, says EIA. Five deepwater projects began in the last three months of 2014: the Stone Energy-operated Cardamom Deep and Cardona projects; the Chevron-operated Jack/St. Malo fields; the Murphy Oil-operated Dalmatian project; and the Hess-operated Tubular Bells project.

Monthly oil production from U.S. federal Gulf of Mexico (2010-2016)



Source: US Energy Information Administration

Note: Production data have not yet been reported for four of the eight fields (Cardamom Deep, Jack, St. Malo, and Tubular Bells).

Also occurring at the end of 2014 was the redevelopment of Mars (Mars B) and Na Kika (Na Kika Phase 3), both of which are mature fields. Cardamom Deep, Jack/St. Malo, and Tubular Bells were slated for a late 2014 start-up as well. The EIA did note that while industry press releases have indicated these fields have started producing, their production data have not yet been reported to the Bureau of Safety and Environmental Enforcement (BSEE) under the US Department of the Interior.

The relatively high number of fields that came online in 2014, and are scheduled for first oil in 2015 and 2016, reflects the revival of interest and activity in the GoM following the Macondo incident and subsequent deepwater drilling moratorium. While the moratorium officially lasted from April 30 to October 12, 2010, there were relatively few field start-ups in 2011 through 2013, the report notes.

Thirteen fields are expected to start up in the next two years, eight in 2015 and five in 2016. The report also noted that the high cost of surface structures limits their application to large fields. Those fields with reserves not large enough to justify the necessary capex are expected to use subsea tieback systems to connect to nearby existing platforms. More than half of the projects starting up in 2015 and 2016 will be subsea tiebacks to existing production platforms. These new projects, combined with continuing production from the developments brought online in late 2014, are forecast to add 265,000 b/d by the end of 2015. The production estimates for 2015 and 2016 include adjustments to account for seasonal shut-ins from hurricanes.

The current low oil price adds uncertainty to the timelines of deepwater GoM projects, says EIA, with projects in early development stages exposed to the greatest risk of delay. In an effort to reduce this risk, producers are collaborating to develop projects more cost-effectively, to shorten the time to final investment decision and

first production, and by sharing development costs. For instance, Chevron, BP, and ConocoPhillips recently announced a collaborative effort to explore and appraise 24 jointly held offshore leases in the northwest portion of the Gulf of Mexico's Keathley Canyon.

Big Foot heads out to the deepwater Gulf

Chevron Corp. says that its *Big Foot* platform safely sailed away from Corpus Christi, Texas, and is now en route to its offshore location in the Walker Ridge Area of the deepwater GoM.

The platform was successfully floated through the La Quinta Ship Channel and is being towed to site at approximately 225 mi (360 km) south of New Orleans, Louisiana, in water depths of 5,200 ft (1,600 m).

Once safely anchored to the ocean floor, the offshore hook-up and commissioning work will commence, followed by the development well drilling and completion campaign.

The *Big Foot* platform is a dry-tree extended tension-leg platform (ETLP) with an onboard drilling rig and production capacity of 75,000 b/d of oil and 25 MMcf/d of natural gas. The hull was fabricated in South Korea, with the topsides fabricated in Ingleside, Texas. Up to 200 people can be accommodated on the platform.

The *Big Foot* field was first discovered in 2006, and Chevron sanctioned the project in 2010. The field is estimated to contain total recoverable resources in excess of 200 MMboe and will have an estimated 35-year production life. First oil and gas is expected in 2015.

Chevron subsidiary, Chevron U.S.A. Inc. (operator), has a working interest of 60% in the *Big Foot* development, with co-owners Statoil (27.5%) and Marubeni Oil & Gas (12.5%).

BP issues update on Gulf restoration efforts

BP has issued a new detailed report on its efforts to clean up and restore the Gulf in the wake of the 2010 Macondo incident.

The company has been working with state and federal trustees through the natural resource damage assessment (NRDA) process to collect data to evaluate the potential for injury to wildlife and habitat, and the recreational use of these resources.

According to BP, more than four years of environmental assessment data suggests that most of the impact on the environment was of short duration and limited in geography. A number of physical, biological, and chemical processes acted upon the oil after it was released from the wellhead, causing the volume and concentration of oil to decrease as it travelled away from the well. In the five years since the spill, scientific data and studies are showing that the Gulf environment is returning to its baseline condition.

The Gulf of Mexico Environmental Recovery and Restoration report also indicates that impacts from the spill largely occurred in the spring and summer of 2010.

The report is based on scientific studies that government agencies, academic institutions, BP, and others conducted as part of the spill response, the ongoing NRDA process or through independent research.

BP and the trustees have been using the cooperative field work data developed through the NRDA process to evaluate injuries to natural resources and to guide the selection of early restoration projects and longer-term restoration of the Gulf Coast. The goal is to return the environment to its baseline condition – the condition it would be in if the accident had not occurred.

Since May 2010, BP has worked with state and federal trustees to develop and implement more than 240 initial and amended work plans to study wildlife, habitat and the recreational use of these resources. By the end of 2014, BP says it had spent approximately \$1.3 billion to support the assessment process. More details on the report can be found on BP's website. ●



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Two multiphase compressor units at the OneSubsea facility in Horsøy, Norway. (Photo courtesy OneSubsea)

Gulfaks South receives subsea multiphase compressor

OneSubsea, a Cameron and Schlumberger company, has delivered the world's first subsea multiphase compressor to Statoil for the Gulfaks South field in the North Sea. The compressor enables boosting of unprocessed wet gas production fluids, while eliminating the need for an upstream separation facility or an anti-surge system, making it what the company says is the industry's only true wet gas compressor. It is a contra-rotating machine specifically designed for pressure boosting of unprocessed wellstream, and is expected to increase the recovery rate for the Gulfaks South Brent reservoir by 22 MMboe.

Jee secures phase two of tidal energy development contract

Jee Ltd. has been awarded phase two of a contract with Scottish Enterprise to undertake the demonstration of its U-tube system in Scottish tidal waters.

Jee's protection system, the U-tube, features a pipe fixed to a J-tube which is secured to the turbine foundations at each end of the pipe. The cable is then pulled vertically into one of the J-tubes and through the pipe using a pre-installed messenger and winch line. Once the cable is pulled in, connections are made to the turbine nacelles using wet-mate connections. The U-tube system provides the marine contractor with full control of the cable installation, which can be stopped and reversed if necessary, offering a high level of flexibility.

In September 2014, Jee secured a phase one contract with Scottish Enterprise, which involved a study for the marine energy industry in Scotland. Aquatera Ltd. is responsible for installation.

FES to supply bend stiffener connectors for deepwater Egina project

Saipem has awarded FES International a \$2 million contract to supply bend stiffener connectors to Egina project offshore Nigeria, Total's third deepwater offshore development in Nigeria. The Egina project consists of five dynamic umbilicals and the bend stiffener connectors will connect them to the FPSO vessel. FES International has started work on the contract, which will be delivered by May 17, 2015. The field is scheduled to start production by the end of 2017.

McDermott, Petrofac form subsea construction alliance

McDermott has formed a five-year alliance with Petrofac to pursue deepwater subsea, umbilical, riser, and flowline (SURF) projects. The two companies plan to offer a wide range of engineering,

procurement, construction, and installation (EPCI) subsea services for deep and ultra-deepwater projects (above \$200 million in value) across the US and Mexican sectors of the Gulf of Mexico, Brazil, the North Sea, Mediterranean, and West Africa.

The alliance will combine McDermott's SURF fleet, its new derrick lay vessel *DLV 2000* and subsea fabrication capability with Petrofac's new deepwater *JSD 6000* installation vessel, currently under construction.

JSD 6000 is designed for ultra-deepwater pipelay, subsea lowering and above surface construction work, through its combined j-lay, s-lay, and ultra-heavy lift capabilities.

INTECSEA lands Buckskin/Moccasin FEED

Chevron has selected INTECSEA to provide engineering and long-lead procurement services for the front-end engineering and design (FEED) phase of the Buckskin/Moccasin development in the Gulf of Mexico. The award comes as an integrated WorleyParsons and INTECSEA team recently completed pre-FEED for the development.

Under the contract, INTECSEA will execute the FEED and procurement services for a subsea tieback from the Buckskin and Moccasin fields to a nearby production facility located in the outer continental shelf of the Gulf of Mexico. INTECSEA offices in Houston will execute the project, with support also coming from the company's office in Hyderabad, India.

Cougar supplies buoy supported riser control system for Balltec use

Cougar Automation has developed and commissioned a control system for Balltec to use on the first buoy supported riser (BSR) system installed on Brazil's Guara-Lula project.

Cougar Automation was commissioned by Balltec to design a dedicated control and automation system consisting of a surface-mounted primary control that powers the movement of the buoy support system via tether adjustment, using a linear chain tensioner. This was required in order to manage the tension in the risers. The system allows surface control of the subsea tensioner system via an ROV. Once over-board, the ROV facilitates establishment of the data pathway to link the surface control to the subsea control modules. The surface control is then used to effect buoy movement as required.

Operated by Petrobras in the Santos basin, the BSR system consists of four submerged buoys each weighing approximately 2,000 metric tons (2,205 tons) which lie around 300 m (984 ft) below sea level.

Deep Blue Engineering plans ROV-based cargo carrier

Deep Blue Engineering Ltd. is developing the Shuttle Sub, a cargo carrier based on the concept of a large ROV with payload capacity, deployed from a support vessel at the surface. As planned, it could be used to conduct a range of installation, heavy-lift, and deployment operations. It will have a modular payload "cartridge" system, making it capable of pipe installation, cable deployment, salvage work, and subsea intervention. Installation functions will be conducted by the Shuttle Sub with no requirement for assistance from a smaller work class ROV during most operations.

Shuttle Sub will be capable of transporting and laying up to 100 tons (90 metric tons) of pipe during each trip from the support vessel. Each pipe will be extracted from the hopper by two manipulators, which can be used to position and align the pipe, and then insert it and make up a connection. To receive a fresh container of pipe, the Shuttle Sub would return to surface. The empty pipe cargo is replaced with a loaded container for the Shuttle Sub to return to the surface and continue with installation. Shuttle Sub is fitted with multiple manipulators, so it will not be limited to installing straight pipe.

Trials are planned for the prototype sub during October 2015. ●



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Floating production deployment spend to total \$81 billion from 2015-2019

Douglas-Westwood's "World Floating Production Market Forecast 2015-2019" predicts that despite the current low oil price environment, between 2015 and 2019 \$81 billion will be spent on FPS units – an increase of 73% compared to 2010-2014. The value of annual installations is projected to grow from nearly \$12 billion in 2015 to \$21 billion in 2017 before declining to \$17 billion in 2019. Projects already ordered will account for much of this spend.

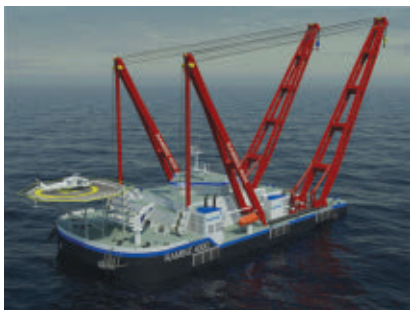
Despite capex growth, the outlook this year for orders is poor, Douglas-Westwood stated. The low oil price is expected to impact the market, leading to a number of delayed project sanctions. This can be seen in the declining number of orders for 2015 and subsequent installation decline in 2018. Projects already under construction are unlikely to be affected.

FPSOs represent by far the largest segment of the market both in numbers (87 installations) and forecast capex (81%) during 2015-2019. TLPs account for the second largest segment of capex (9%) with FPSOs third (7%).

Latin America will see nearly one-third of the 110 installations forecast and 32% of the projected capex.

Scaldis orders newbuild DP-2 crane vessel

Scaldis Salvage & Marine Contractors NV ordered a self-propelled DP-2 crane ship from Royal IHC. Delivery is scheduled for spring 2017 in Europe. The vessel will be built under full responsibility and coordination of Royal IHC in Qidong and finished in Xiamen, both in the People's Republic of China.



Rendering of Scaldis new self-propelled crane ship. (Drawing courtesy Scaldis)

The design was drawn up in-house in cooperation with Vuyk Engineering Rotterdam.

The ship is designed to have two Huisman cranes each with a lifting capacity of 2,000 tons. The ship also has extra carrying capacity of 3,000 tons. The cranes can be moved by 25 m (82 ft) on the ship. This allows the deck to be used to transport and then relocate cargo at a later stage, said Scaldis.

The maximum load will be able to be hoisted in significant wave heights of up to 1.5 m (5 ft). In standby or transport modes, significant wave height can be as much as 7.0 m (23 ft). The maximum load can be lifted in water depths of around 5 m (16 ft).

Coastal Offshore sells two offshore support vessels

Coastal Offshore (Labuan) Pte Ltd. has secured contracts for the sale of two offshore support vessels for an aggregate value of approximately RM197 million (\$54 million). Both of these vessels were sold to customers in Mexico and are expected to be delivered in 2015 and 2017.

Goliat platform readies for Norway

The Goliat platform has been towed on board the *Dockwise Vanguard* and is ready for departure to the Eni-operated Goliat field in the Norwegian sector of the Barents Sea. At 107 m (351 ft) in diameter, the Goliat platform is the largest cylindrical FPSO facility ever built. It was designed by Sevan Marine in Arendal especially for the Arctic conditions of the Barents Sea, and was built at Hyundai Heavy Industries' yard in South Korea. The Goliat field FPSO has a produc-

tion capacity of about 100,000 b/d and a 1 MMbbl storage capacity.

The Eni-operated Goliat field is the world's northernmost offshore oil field, and will be the first oil field to come into production in the Norwegian sector of the Barents Sea. The field is expected to come onstream in 1H 2015.

The platform will be supplied with electrical power from the mainland using the longest submarine cable of its type in the world.

ABS certifies software integration on third Rowan drillship

Completion of the *Rowan Reliance* drillship marks the third delivery of high-specification units built at HHI using the ABS ISQM process. This newbuild, the third in a series for global offshore drilling contractor Rowan Companies built in the Hyundai Heavy Industries yard in Ulsan, South Korea, joins sister ships *Rowan Renaissance* and *Rowan Resolute* as the next high-specification drillship to earn the ABS Integrated Software Quality Management (ISQM) notation.

ABS says ISQM addresses the challenge of making sure the many pieces of software that enable efficient operations of the rig are able to maintain reliable communications by providing a framework for coordinating and controlling the way software development, integration, and maintenance are managed throughout the life of the equipment.

HHI will follow the ISQM process in the construction of the final drillships in the four-unit series, the *Rowan Relentless*, which is expected to be completed in 2Q 2015.

"ABS is the only class society that has classed drilling equipment and other essential marine equipment with a software notation that addresses software quality during construction, at delivery and into operations," says Paul Walters, ABS Manager.

"Working with ABS and Rowan Companies on this project has allowed HHI to develop a knowledge base that allows us to offer experience with a new process that will benefit not only Rowan but other clients that choose to take advantage of the ISQM process," says Sang-Sik Yoon, ISQM Team Leader, HHI.

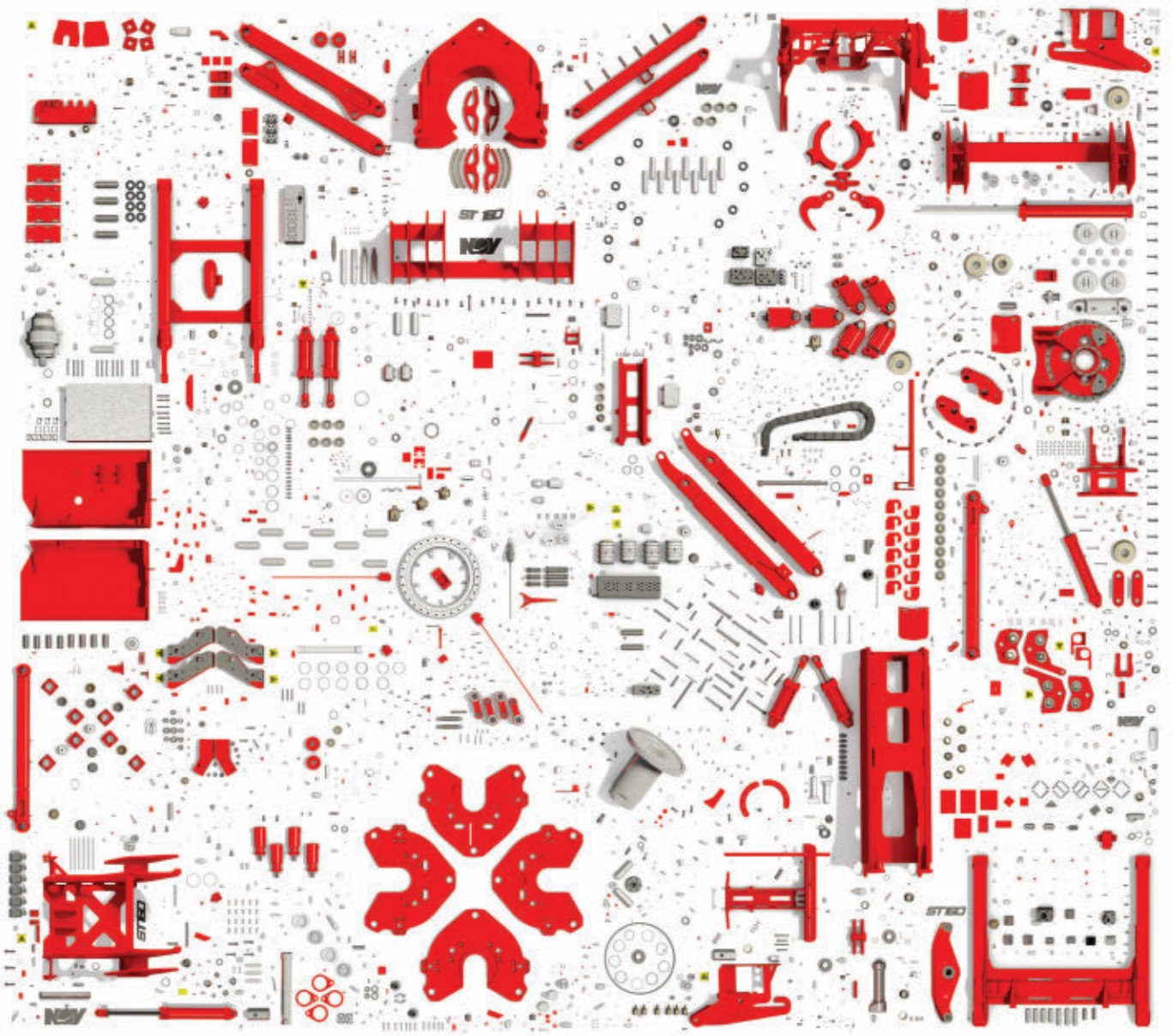


Ocean Tay is a Class A emergency response and rescue vessel. (Photo courtesy Atlantic Offshore Rescue)

Atlantic Offshore commissions rescue craft for Nexen charter

Atlantic Offshore Rescue has commissioned a £6-million (\$9.2-million) vessel for a long-term charter with Nexen Petroleum UK Ltd. The new vessel, *Ocean Tay*, is a Class A emergency response and rescue vessel (ERRV), which will provide emergency vessel cover for Nexen's Golden Eagle Area development in the North Sea. The charter will last a minimum of two years.

Ocean Tay underwent conversion at Wear Dock & Engineering Co., Sunderland, to become one of a fleet of 12 ERRVs Atlantic Offshore Rescue manages out of Aberdeen. The 63-m (207-ft) vessel can accommodate a crew of 20 and as a Class A ERRV can rescue in excess of 300 persons. ●



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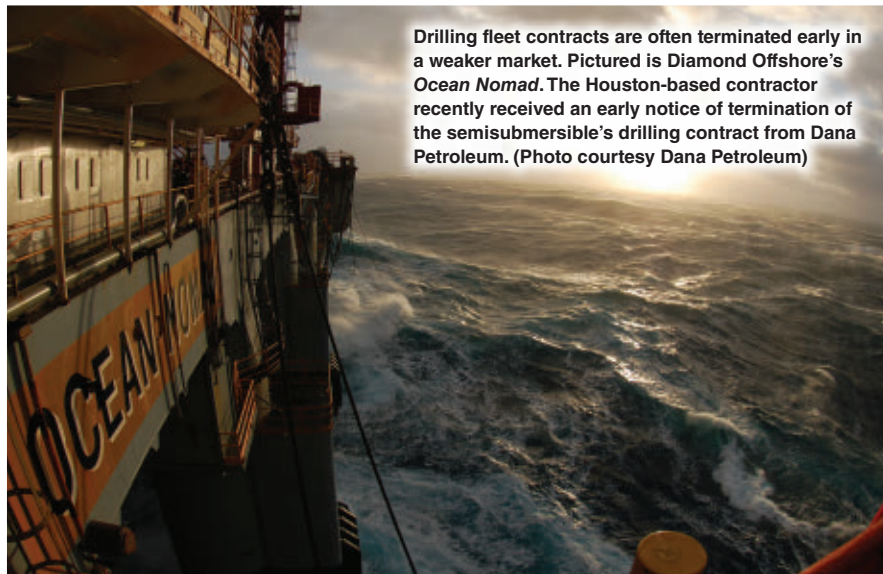
Down-cycle market calls for advanced planning

Every day, the news is peppered with stories dealing with the effect of the commodity price downturn. In them, an amazing amount of companies are quoted as saying something like, "We hope this is only a short down-cycle, and that we have a quick recovery." This is almost like acknowledging the obvious by saying, "We hope the sun rises again tomorrow." However, any seasoned oil executive will tell you that hope is not a plan.

Neither is buttoning down the hatches and riding it out. Whether the current down-cycle is of short duration or prolonged, all companies need to react appropriately to the reality that faces the industry. After previous down-cycles, many companies have developed detailed contingency plans to trim the fat and cut costs. This applies to operators as well as service and supply companies. Plan for the worst; hope for the best.

The trigger point depends on the financial status of the company. Some are heavily leveraged and must move quickly; others can implement a staged approach.

For example, the drilling fleet represents one of the highest cost items on the balance sheet. Operators with long-term contracts for high-specification drilling units can seek sub-leasing opportunities to take their contracted rigs off their own books and put them onto someone else's. Many operators faced with drilling to hold their leases can satisfy this requirement with a well-by-well project using rigs acquired in this secondary market.



Drilling fleet contracts are often terminated early in a weaker market. Pictured is Diamond Offshore's Ocean Nomad. The Houston-based contractor recently received an early notice of termination of the semisubmersible's drilling contract from Dana Petroleum. (Photo courtesy Dana Petroleum)

Larger offshore contractors are already stacking some rigs as well as delaying delivery of those under construction in various shipyards around the world. Early retirement of older, less capable units can reduce costs without jeopardizing the ability to recover once the hoped-for upturn arrives.

Everywhere, the loss of experienced personnel is of high concern. In previous downturns, the industry lost highly skilled people who joined other industries and never returned. Hard experience has taught painful lessons in the human resources area. As an example, during an earlier recession, one company waited

until the last possible moment to cut personnel; the company was then forced to make deep slashes with little opportunity to evaluate those involved. As a result, many people who should not have been released were cut. Today, this company has developed formal rolling evaluation plans so each manager knows who his or her bottom 20% of performers are at any time. When a downturn occurs, these individuals can be laid off without jeopardizing the company's ability to recover once the crisis is over. For regional downturns, many companies can solve overcapacity by transferring workers to areas less affected by the downturn. However, the relocation costs can be considerable, so this practice has its limitations. A third process is early-retirement of qualified employees, which can be an effective way to lower the headcount somewhat painlessly.

In a macro sense, some service companies are selling off low-profit subsidiary companies to strengthen the remaining team. This procedure can be effective for highly leveraged subsidiaries, or those with a high ratio of hard assets.

Ironically, many companies decide to cut marketing, possibly under the apprehension that the market is shrinking; therefore, sales and marketing departments should be severely cut-back. This is false economy, because the marketing departments represent the ability to grow the business, which is exactly what's needed in a business slump. Advertising and self-promotion can help grow market share in a declining market. A better solution would be to cut loss-leaders and focus on growing the most profitable departments, using a strong marketing team to identify and target high potential market opportunities.

Of course, everyone hopes the recovery will be quick and strong. But only those with a plan will be around to experience it. ●

OTC promises technical solutions

The 2015 Offshore Technology Conference and Exhibition will take place at Houston's NRG Park (formerly Reliant Park) during May 4 - 7.

Many breakthrough developments have been thoroughly field-tested and will make their commercial debuts at OTC. The exhibition has identified a variety of innovative tools, techniques and products through its "Spotlight on Technology" awards program. Winners were selected from a large number of entries by a panel of experienced judges who looked for ideas with the greatest degree of innovation and highest potential for profitability and safety.

The exhibition offers an excellent opportunity for visitors to meet with international exhibitors. In addition to the exhibits, the technical program supports technology transfer and gives visitors the opportunity to meet and confer with experts who may have solutions to their biggest challenges.

OTC conference organizers provide the following tips for getting employer support for you to attend:

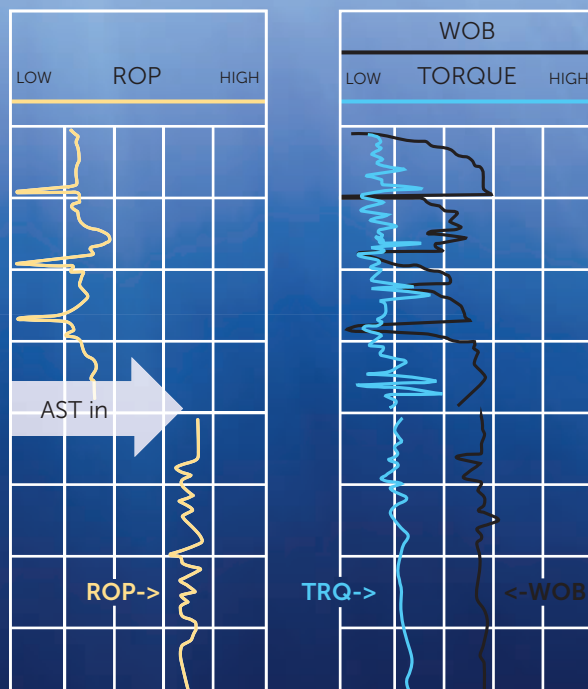
- Offer to prepare and deliver a short presentation to your colleagues to share what you learned. That way, others on your team will gain the benefits of your attendance.
- Explain what you plan to get out of attending and how that will benefit your company.
- Be ready with a plan that shows who will cover for you while you are attending the conference.
- Offer to share a room to reduce hotel expenses and/or utilize complimentary hotel shuttle service at official hotels to avoid renting a car.
- Share presenter handouts and exhibiting companies' materials with your colleagues.
- If you are a member of one of OTC's sponsoring, endorsing or supporting organizations, you can take advantage of discounted registration.
- Meet with clients before/during/after OTC to maximize time spent in Houston.

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The use of the AST in combination with sensitive drilling tools such as under-reamers is a field-proven solution that has halved drilling times in offshore operations globally.



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CGG starts Davros 3D multi-client survey offshore Australia

CGG has started acquiring the Davros 3D BroadSeis and BroadSource multi-client survey in the Northern Carnarvon basin on the North West Shelf offshore Western Australia. At more than 11,000 sq km (4,247 sq mi), Davros is the largest seismic survey ever acquired by CGG in the Asia/Pacific region.

The Davros survey is being conducted by the *Viking Vision*, using CGG's BroadSeis variable-depth streamer configuration and BroadSource synchronized broadband multi-level source. The vessel is equipped with 12 Sercel Sentinel RD 2 Hz streamers, each measuring 5.1 mi (8.2 km). The data will be imaged by CGG using technology including pre-stack depth migration.

The Davros survey is designed to address the imaging challenges of the Rankin Trend, such as the effects of the high-velocity carbonate overburden, steeply dipping structures, fault shadow, and structural complexity at depth, all critical for selection of drilling targets.

Jean-Georges Malcor, CEO of CGG, said: "We believe Davros will reveal exciting new exploration opportunities, given its location adjacent to significant discoveries along the Rankin Trend. With the unique combination of BroadSeis with BroadSource and our advanced subsurface imaging technology it will significantly enhance interpretation of the area's Triassic to Lower Cretaceous reservoir units, which exceed 10 km (6.2 mi) in thickness and are expected to host significant quantities of hydrocarbons, as has been confirmed by these previous discoveries."

CGG in 2015

In wrapping up 2014 and looking forward, CGG is in a new phase of its Transformation Plan

2015. Included in this new phase is a further fleet reduction from 13 vessels to 11 vessels and a capex reduction of about 25% for 2015.

The Transformation Plan launched at the end of 2013 and accelerated in 2014, has resulted in a 12% reduction in headcount, and a fleet reduction from 18 to 13 vessels.

SeaBird to lay up two seismic vessels

Another company addressing the weakness in 3D seismic demand is SeaBird. It has chosen to lay up the *Geo Pacific* as soon as it completes an African project. It will join *Voyager Explorer* taken out of duty in late 2014. The company anticipates redelivery of the *Geo Pacific* sometime this year, and the return of the *Voyager Explorer* next year.

SeaBird expects the global seismic market demand to be soft through 4Q 2015. The decline in oil prices and the cautious spending by oil companies delayed contract start-ups and reduced seismic demand. Nevertheless, SeaBird continues to secure additional 2D contracts and strengthened its 2015 backlog.

Offshore seismic project awards

While some companies see offshore seismic demand in decline this year, that does not mean there is no activity.

Polarcus Ltd. has an award from an undisclosed client for a 3D marine seismic project offshore Egypt using Polarcus' RightBAND technique for broadband data acquisition. The project should already be under way and nearing completion.

Chariot Oil & Gas Ltd. has a 2D seismic acquisition survey covering about 1,700 km (1,056 mi) in central blocks 2312 and 2412A

offshore Namibia. SeaBird Exploration has the contract.

Chariot and its partners have agreed to initially carry out a 2D survey, which will infill an existing grid of data in order to better understand the regional prospectivity of this license area (which covers approximately 16,800 sq km/6,487 sq mi). Chariot says this will enable it to optimize the design of the location and size of the 3D seismic program required as a commitment during this current phase of exploration.

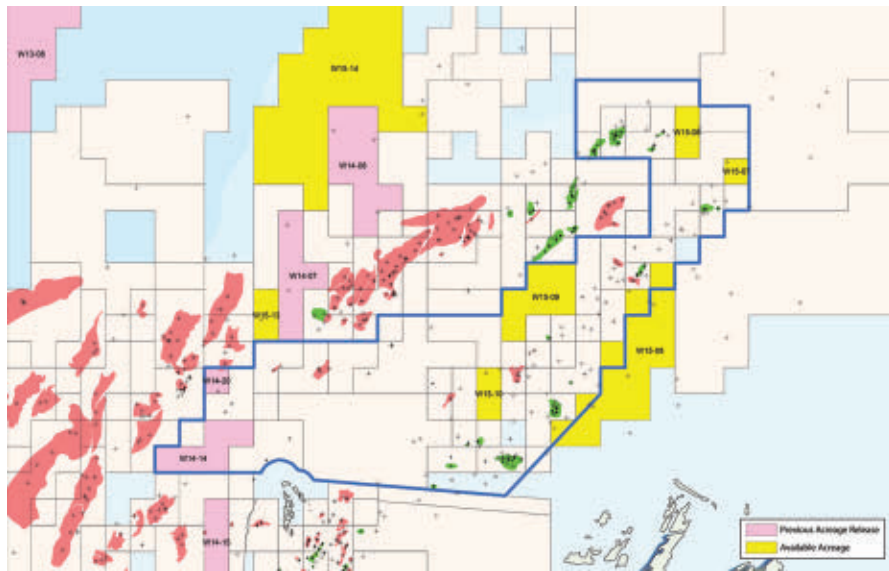
Electromagnetic Geoservices ASA (EMGS) will receive a revenue lift of \$2.5 million related to the licensing round for mature areas on the Norwegian continental shelf – Awards in Pre-defined Areas (APA). EMGS says its multi-client data library in Norway now covers 44,000 sq km (16,988 sq mi) in the Barents Sea, in addition to approximately 10,000 sq km (3,861 sq mi) in the Norwegian Sea and 1,400 sq km (541 sq mi) in the North Sea.

Searcher Seismic and DownUnder Geo-Solutions have agreed to market and license the Monodon Ultracube. The Monodon Ultracube consists of approximately 14,700 sq km (5,676 sq mi) of 3D and 2,000 km (1,243 mi) of 2D reprocessed data in the prospective Northern Carnarvon basin of the North West Shelf, Western Australia. The project incorporates a total of 16 individual 3D surveys and three 2D surveys shot between 1982 and 2004 and includes the reprocessing from field tapes using a state-of-the-art flow and cutting edge algorithms that include industry leading linear noise removal and regularization. The reprocessed data has been merged prior to anisotropic (TTI) pre-stack depth migration incorporating multi-iteration tomographic model building.

UT enhances geoscience research ties with Mexico

The National Autonomous University of Mexico (UNAM) and University of Texas' Jackson School of Geosciences will strengthen collaboration in the fields of energy, environment, and sustainability. The new agreement focuses on academic research in the earth sciences and engineering. It highlights the importance of Mexico to the Jackson School Department of Geological Sciences and the school's two research units – the Bureau of Economic Geology and the Institute for Geophysics. The new partnership will enhance the mutual academic opportunities created by Mexico's recent energy reform.

The new partnership will promote the mobility of postgraduate students, researchers, and faculty between the institutions. It will also help facilitate conferences, symposia, and joint academic programs and scientific research projects to identify and meet sustainable energy challenges. ●



CGG is working on its largest-ever seismic survey in the Asia/Pacific region with its Davros project offshore Western Australia. (Map courtesy CGG)

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Effective data management, interpretation improves reliability

Ian Verhappen

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In the offshore environment, the life cycle normally begins with a conceptual design or change request and proceeds through engineering, then construction to commissioning/operations, which often includes repair/replacement, until finally it is time to be retired or decommissioned.

Every physical asset in a facility also requires three types of information: design information that is typically recorded on a data sheet; physical asset information describing the device itself, which is normally tracked by the serial number; and the device output, which is the measurement signal often represented by the device tag name. Each of these three aspects of the device will have a different life cycle.

The most commonly considered information type – at least by automation engineers – is the design information commonly documented using ISA20 based data sheets. The information for the data sheets is now commonly stored in databases with the actual “data sheet” as a report or form. Databases work best when data input is uniform or consistent and as a result the preference is to have drop-

down menus for as many fields as possible.

German end user group NAMUR (User Association of Automation Technology in Process Industries) started a project called ProList that formed the basis for the work of SC65E WG 2 product properties and classification, which is completing a series of standards to help manage the life cycle of field devices.

The working group is developing documents (actual databases) that provide a method for standardizing the descriptions of process control devices (measuring equipment) and specifies how to use the device descriptions for electronic data exchange between two computer systems, e.g. one of a customer and one of a supplier, applying properties and lists of properties. The intent is that customers and suppliers will subscribe to a common secure IEC 61987-10 compliant database.

The databases use the predefined fields (list of properties or LOPs) further separated into operating lists of properties (OLOPs) and device lists of properties (DLOPs). OLOPs describe the process related characteristics including the process connection(s) while the DLOPs are used to define the required properties specific to the device such as type of temperature measur-

ing element, fill fluid, or seat material. Eventually, the intent is that this tool will be able to manage additional portions of the product life cycle.

The diagnostic information as well as the physical asset information is normally maintained in an asset management or maintenance management database to track the device itself. Each device is tracked by the supplier to keep records of each product series for reliability and use in different applications as inputs to product improvement opportunities. Each device is tracked by the end user to track total hours service (i.e. pumps, valves) between required maintenance work and reuse in a different application when it returns from repair.

The life cycle for each of the identified databases/assets is different. The data sheet and tag numbers will typically be valid for the time period of the process to which it is connected. If a part of a facility is upgraded, the measurement is still likely to be needed but may change range or even measurement type (i.e. orifice to vortex flow meter) over time. Obviously, over the 20-plus years that a facility operates, several of the field assets will need to be replaced so there are

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Hoang Long taps Honeywell for third offshore Vietnam production platform

Hoang Long Joint Operating Co. (HLJOC) has contracted Honeywell Process Solutions to provide project management and engineering for a third production platform offshore Vietnam.

The new contract covers engineering management and integration with the two existing Te Giac Trang (TGT) platforms, the FPSO that processes the hydrocarbons produced by the platforms, and remote monitoring from the HLJOC office in Ho Chi Minh City.

Along with turnkey project management and engineering of the new platform's topsides structures, HPS will install an integrated control and safety solution, including a new fire and gas system, to improve automation, increase cyber and physical security, and improve operator effectiveness.

HLJOC will operate the TGT-H5 wellhead platform located in the TGT field off the southern coast of Vietnam. TGT-H5 plans to begin production in 4Q 2015. Total production from the three platforms is expected to be about 50,000 b/d of crude oil.

HLJOC is a state-owned partnership between PetroVietnam Exploration and Production Corp., SOCO Vietnam Ltd., OPECO Vietnam Ltd., and PTT Exploration and Production Co. Ltd.

likely to be several versions of this data type affiliated with the related data sheet and tag number. Managing the relationship between the data sheet/specification and physical asset can often be done using something as simple as an effective document management system with a consistent revision control component.

The challenge with any document management system, however, is keeping it current and hence relevant and that is as much a people issue as anything else which means it is difficult to manage.

At the end of the facility's life, some parts of the facility will have been replaced or decommissioned multiple times, while other assets will have been partially replaced (again once or multiple times) and others not at all. Regardless, the information and data on health of the equipment will be part of the determination for when a facility is to be decommissioned since it is this data that tells us when to schedule an outage, what work needs to be done, and as a result based on the required investment whether it is economic to continue to operate a facility versus closing, mothballing, or dismantling it. The field sensors and controllers are but a small part of an offshore facility, but the data they provide is often the basis not only for how the facility operates but also when

perform maintenance is needed.

The challenge is managing the data through the entire life cycle because it is important for not only the individual device but also the facility to which it is connected. Those organizations that have been able to "deal with the data" and make effective use of the information resulting from its effective interpretation are quickly becoming "best in class" leaders with reduced operating costs and improved reliability. ○

The author

Ian Verhappen, PEng, is an ISA Fellow, ISA certified automation professional, Automation Hall of Fame member, and a recognized authority on process analyzer sample systems, Foundation Fieldbus, and industrial communications technologies. Verhappen provides consulting services in the areas of field level industrial communications, process analytics, and hydrocarbon facility automation. Feedback is always welcome via e-mail at iverhappen@gmail.com.

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Governments advance emerging plays in Eastern Mediterranean, North Atlantic

Increased seismic, studies shed new light on existing acreage

Basins in the eastern Mediterranean Sea are of increasing interest following the discovery of deepwater gas offshore Israel. However, some of the newly-licensed areas could be more prospective for oil, according to presentations at IRN's Oil & Gas International Licensing Summit in London earlier this year.

Interest is growing too in the North Atlantic since Statoil and Husky Energy proved oil earlier this decade in the deepwater Flemish Pass basin off Newfoundland & Labrador. The provincial government is now looking to ratchet up exploration much farther north, based partly on analysis of one of the world's largest-ever 2D seismic surveys over a frontier offshore province.

Croatia overhaul

Neil Hodgson, Spectrum ASA's executive vice president, Mediterranean and Middle East Region, outlined how his company supported Croatia and Lebanon's recent licensing rounds. Earlier this year, Croatia's government awarded licenses for 10 offshore exploration blocks to Marathon, OMV, Eni,

Jeremy Beckman
Editor, Europe

Medoigas Italia, and Croatian oil company INA.

Explorers new to this part of the Adriatic Sea, Hodgson said, are looking to find oil, not gas. To generate interest in the round, the government invited Spectrum to examine its existing petroleum database, including a review of its legacy seismic data. Much of this old 2D data was acquired by INA between the 1970s and 1990s, and most of it was in poor condition. INA was subsequently privatized and the data transferred to a new department.

"They didn't know what to do with the information," Hodgson explained, "so they asked us to build a data room for them, providing international oil companies with legacy data organized in such a way that it could be interpreted to establish basins and plays." Spectrum reprocessed some of

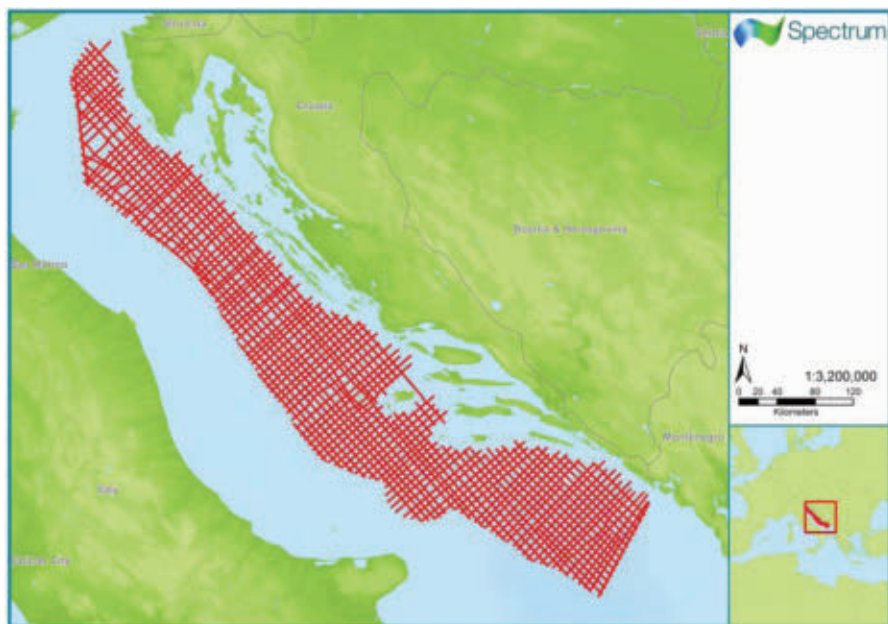
the data, updating it with new algorithms to give a clearer picture of the geology, which Hodgson said makes it easier for oil companies to pinpoint source rocks and so on. Additionally, the company created a website for the government to promote the fact that it was planning a licensing round, inviting Croatian officials to various conferences to assist this process.

Aside from the legacy seismic, Spectrum scanned and re-digitized well logs from 51 offshore wells into a package that bidders could analyze. "We also acquired complementary new gravity and seep data sets [based on satellite images of thousands of seeps in an area covered by tourist boats]. This information is critical for licensing rounds, as current exploration involves a mixture of CSEM [controlled source electromagnetic], gravity, seep data, and remote sensing, all integrated to achieve a picture that makes interpretation more confident.

"We felt that most interested companies had looked at Croatia before. The issue in the past has been with the area's hydrocarbon system reservoir charge: If the industry believes there is not much potential, we won't get many IOCs knocking at the door. We had to create a narrative to address these facts, so we also acquired and interpreted nearly 15,000 km [9,321 mi] of new 2D seismic."

The resultant data allowed Spectrum to improve imaging of potentially prolific Triassic source rock – where this is deposited and where it appears to be mature, and to determine from this where structures might be present and how the basins might work. The company also used the new data to map out a Mesozoic carbonate platform play that had not been visible on the old INA seismic, and to explain why the earlier dry wells had missed their targets. If INA had been able to access this data, Hodgson said, it would have found hydrocarbons.

There are oilfields on the Italian side of the Adriatic, he pointed out; the prospects are closer to the source rocks on the Croatian side. Therefore, there is potential for oil in greater volumes. "Again, that insight is only available on the new data."



Seismic grid over acreage offshore Croatia. (Map courtesy Spectrum)

Lebanon licensing preparations

Lebanon's government opened the country's first offshore licensing round in December 2012. No wells had previously been drilled off the country's shores, although the Lebanese offshore was covered extensively by a dense grid of 2D seismic. Some of this data was acquired by Spectrum in the early 2000s. The government also encouraged Spectrum and PGS to perform a multi-client 3D survey over 70% of the offshore area prior to opening the licensing round.

It is unusual to find this level of coverage in a frontier unexplored area, Hodgson said, "but the availability of 3D seismic definitely energizes a licensing round, knocking three years off the initial work program. Instead of spending the first term chasing seismic, they can prepare for drilling wells."

South of Lebanon, Noble Energy discovered the 8 to 9-tcf Tamar gas field in 2009 in the Israeli deepwater sector, followed by the 25-tcf Leviathan and 6-tcf Tanin finds. All of the wells drilled to date in the South Levantine basin have delivered very dry biogenic gas, as opposed to heavier thermogenic gas from source rocks, Hodgson explained.

"There is a feeling in the industry of, do we really want to find deep, dry gas in 2 km of water off Lebanon?" he asked.

"The Lebanese Petroleum Administration came together in 2012, but the license process could have been a turn-off to the IOCs if the perception was just of gas in really deepwater. So we felt it was our job to look at the hydrocarbon picture and generate a different story – again, we needed to create a narrative to capture the industry's imagination. The source rock for Tamar is Oligocene – it's too shallow to generate oil, although there is this capability deeper down. If you apply that picture to Lebanon, it may be that offshore oil is generated there."

Hodgson added: "If you follow the seismic reflectors northward Lebanon, the rocks are not 250 m [820 ft] thick, as in Tamar, but more like 1 km [0.6 mi] thick in the northern Levantine basin offshore Lebanon, where the quality is also best. The sands over Leviathan and Tamar both came from the source of the Nile River through the Nile Delta – they are very clean, filling up offshore Lebanon where the best reservoir in the area appears to be.

"In the southern half of the Lebanese offshore, in block 5, we have mapped 25 structures that are invisible on 2D, but clear on 3D seismic. That gives companies the chance to see big connected volumes of reservoirs. We can see potentially 30-60 tcf in these structures at Lower Miocene level, along with two large low-relief structures in the Upper Miocene."

PGS' seismic is over the near-shore Lebanese areas, from 50 to 1,100 m water depth (164-3,609 ft). Spectrum's coverage is over the western part, where water depths range from 1,100–1,500 m (3,609-4,921 ft). "It's not a huge difference in terms of exploration drilling, but that's where the big prospects are."

"In Croatia," Hodgson continued, "the Minister for the Economy wanted the licensing round to serve as a legacy to the country. So he put together a small, relatively young team to change the hydrocarbon law and set up an administrative body. They worked hard and made it happen. In Lebanon, the situation is much more complicated. The Lebanese Petroleum Administration comprises seven members, each from a different sect. Then the conflict in Syria arose, followed by the flight into Lebanon, a country of 2 million people, of 1.5 million Syrian refugees. That delayed the licensing round – each time the decrees were to be signed by Parliament, other matters arose that were much more important.

"Now Lebanon has stabilized, so the two decrees are back on the agenda for Parliament to sign and finally close the licensing round. That will energize the oil and gas community. They may also re-do the qualification exercise, giving opportunities to companies previously excluded from bidding. This situation has stopped Spectrum from promoting the round these past two years, but hopefully 2015 will be a success."

Iceland's experience

Iceland's Hydrocarbons Act became law in 2001 and the country opened its first offshore licensing round eight years later in January 2009, over areas in the north of the Dreki area offshore eastern Iceland. However, the deadline for applications of May 2009 proved to be too short – only two bids were submitted, and both were withdrawn shortly afterwards.

The timing was unfortunate, explained Thorarinn Sveinn Arnarson, hydrocarbon exploration manager for Iceland's National Energy Authority (NEA). "It coincided with the previous slump in the oil price, and it was a frontier area with only limited available data – at the time there were difficulties attracting funds for frontier exploration. We were also still working on our fiscal framework and got a lot of criticism for that, with no standard joint operating agreement [JOA] in place."

NEA sought meetings with applicants to ascertain what went wrong, and how it could improve the bid process in future. For the second Icelandic licensing round, NEA prepared a standard JOA, modeled on the Norwegian version, and rewrote the Hy-

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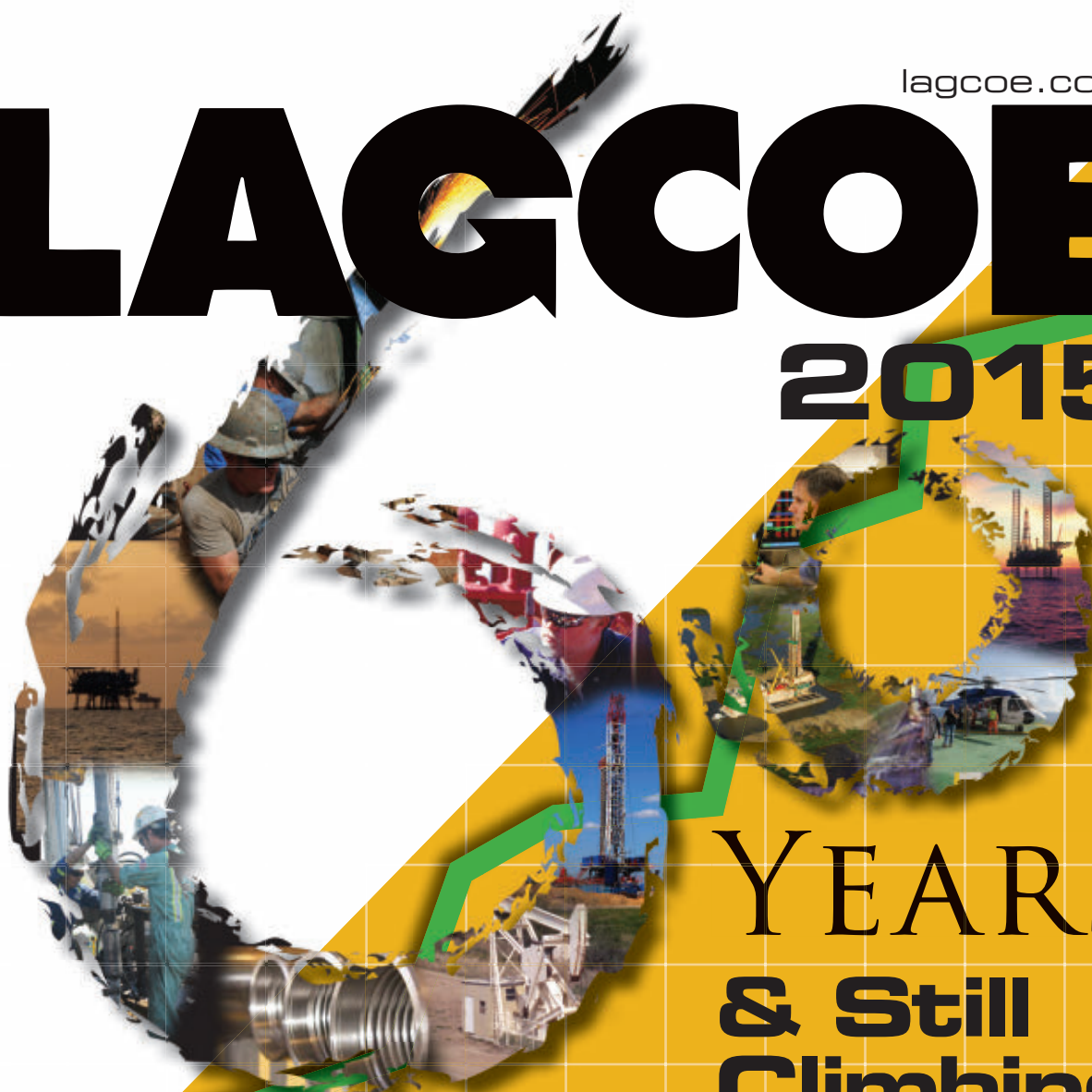


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drocarbons Act. "And we cooperated with Norway on gathering more data," Arnarson said. "So for the second round there was no pre-defined limit on the size of the license areas." Revised fiscal terms included a 5% levy on production and a corporate income tax rate of 20%.

During 2011, TGS performed a seabed sampling survey over the Jan Mayen Ridge area that connects Iceland with Norway. Results suggested evidence of a petroleum system, with seepage of Jurassic oil. This data was made available for the 2nd round over the North Dreki area, announced in late 2011, with the Norwegian state given the right to participate in 25% of any of the three licenses subsequently awarded in 2013.

The consortium of Faroe Petroleum, Petoro, and Iceland Petroleum has since relinquished license 2013/01, after completing the initial two-year work commitments. Their studies suggested that the presence of basalts on the eastern edge of the Dreki area would complicate imaging of underlying sedimentary sequences. However, Ithaca Energy and the Eykon Energy/CNOOC partnership are still committed to their work programs, and plan to acquire seismic this summer over their concessions under a vessel-share arrangement, according to Arnarson.

Newfoundland & Labrador

Nalcor Energy is the provincial energy company for the province of Newfoundland & Labrador. It holds minority interests in three of the main oilfield developments off Newfoundland – Hebron, White Rose, and Hibernia South Extension – and promotes oil and gas exploration in the province's established and emerging basins.

Dr. Richard Wright, Nalcor's exploration manager-oil and gas, said: "We are active at the front end of exploration, de-risking the province's basins and evaluating its offshore resources. We are not competing with private sector companies. If there is a discovery anywhere, Nalcor has the right to back in with 10%, so it is in our interest that the industry finds more, in order to maximize the province's resources."

Newfoundland & Labrador's offshore area extends over 1.5 million sq km (579,000 sq mi). To date, 150 exploration and appraisal wells have been drilled, of which 70 have been in the Jeanne d'Arc basin, where 3.5 Bbbl of discovered reserves are either in, or coming into production, Wright said. The province's other 20-plus basins are all frontier offshore plays, with until recently sparse seismic coverage. Nalcor has been evaluating all of them in terms of potential seal, trap and oil and gas charge, he added, via a series of commissioned studies designed to



Map shows area offshore Newfoundland & Labrador covered by 2011-13 regional 2D seismic program. (Map courtesy Nalcor Energy)

reduce the geological uncertainties.

One of Nalcor's first projects, in association with EADS Astrium, was a regional oil seep mapping and interpretation study in 2010 over the entire area offshore Newfoundland & Labrador south to Nova Scotia. This involved taking satellite images of natural seepage in various basins – not an easy task, with wind and waves constantly acting to disperse the various slicks, Wright pointed out.

Based on the results of this program and legacy gravity and magnetics data, Nalcor invested the following year in a three-year, multi-client 2D seismic survey with partners TGS and PGS which targeted the slope and deepwater plays off the Labrador Sea. The seismic lines were positioned to cover the areas of possible seepage highlighted in the Astrium survey, with data acquired from the shelf out to beyond the 200-nautical mile limit.

In 2012, the partners extended this survey to the southeast to cover the Orphan basin through the Flemish Pass to the outboard regions of the Flemish Cap. In addition, they acquired a 10 x 10-km (6.2 x 6.2-mi) detailed grid over the Flemish Pass in response to interest from the industry following the Statoil/Husky deepwater Mizzen oil discovery (the first oil find outside the Jeanne d'Arc basin, and subsequently followed by the same partnership's Bay du Nord and Harpoon discoveries). By the end of 2013 the seismic acquisition team had compiled 47,000 line km (29,204 mi) of new data in three seasons, one of the large-

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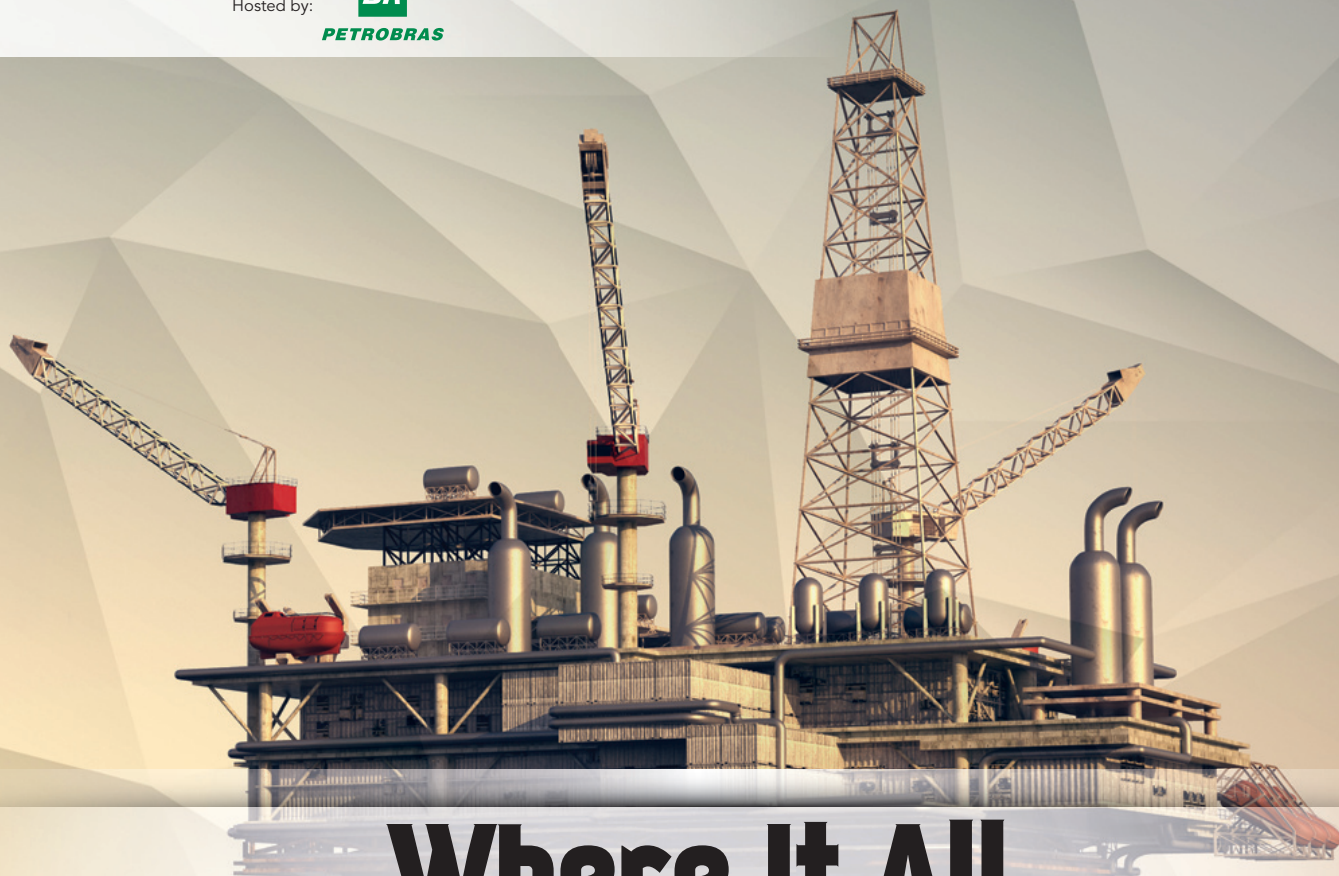


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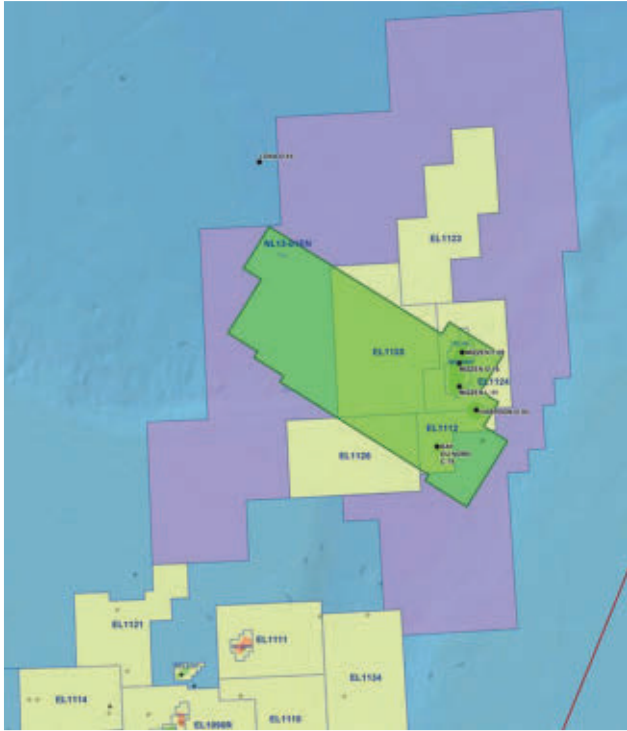
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Area over eastern Newfoundland covered by EMGS 3D EM survey. (Image courtesy EMGS)

Late last year, Nalcor and Ikon Science Canada completed the first-ever regional pore pressure study for offshore Newfoundland & Labrador. This was designed to evaluate the eastern frontier slope and deepwater basins from northern Labrador to the Flemish Pass, including the newly discovered Chidley, Henley, and Holten basins in the Labrador Sea. Additionally, Nalcor and ION Geophysical are collaborating on a rock physics study, designed to help the industry identify potential hydrocarbon features and to distinguish sand from shale. Other planned studies include a seabed survey to understand heat flow imaging and to establish whether

est seismic surveys ever attempted, Wright claimed, and over an area 15% larger than the US Gulf of Mexico.

There has been further activity since, he added, with seismic boats operating offshore Labrador, eastern Newfoundland, and the region south to Nova Scotia. Last year, Nalcor started work with Norwegian contractor EMGS on a 13,500-sq km (5,212-sq mi) multi-client 3D electromagnetic campaign offshore eastern Newfoundland, designed in part to improve understanding of the geology in the vicinity of the recent discoveries.

According to Wright, Petro-Canada was the first to drill an exploration well in the Mizzen area in 2003, but did not have the benefit of long-offset seismic. Data from the recent surveys over Mizzen have revealed a strong anomaly down-dip.

“That caused consternation, because the resistivity was higher than the reading for the discovery location. The seismic amplitude appears to be stronger down-dip – there are lots of analogies in the North Sea,” he said.

Analysis of the regional long-offset southern Labrador 2D data has identified a large tertiary dome feature at the mouth of a river system, and a tertiary fan in the same area of interest, Wright said. "There appear to be similar characteristics to the Forties field in the UK North Sea." The various campaigns have also brought to light analogies with the same play types that opened up deepwater Ghana, he added.

the known source rocks are related to oil seeps; a metocean study to examine wind, waves, currents, and iceberg movements; and analysis by Paris-based Beicip-Franlab of the various identified leads and prospects and the associated risks.

"The new data we've acquired represents the first large-scale program off eastern Canada for 25 years," Wright said, "but how do you assess the reservoirs over such a big area? We chose the deterministic route, focusing on smaller areas and their associated resource potential one at a time."

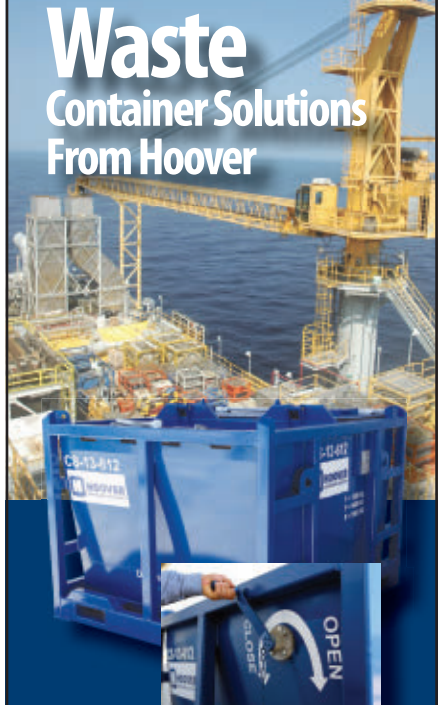
Last December, a consortium of Exxon-Mobil, Suncor Energy, and ConocoPhillips was awarded Parcel 1, a 266,139-ha (2,662-sq km) concession in Area C of the Flemish Pass basin, south of the discoveries, under the Canada-Newfoundland Labrador Offshore Petroleum Board (C-NLOPB) NL-13-01 bid round. Over the next few years, C-NLOPB plans a rolling cycle of parcel nomination and subsequent bid rounds over selected areas, with a longer schedule in the run-up to the awards in order to give the industry more time to assess the exploration potential.

In February, C-NLOPB invited nominations for a second sector in the Eastern Newfoundland Region (details of the first were announced last May). Also in February, the board said it had concluded its assessment of nominations for Sector NL01-LS in the Labrador South and Labrador Offshore areas, and anticipates issuing a call for bids in spring 2017. 📍

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Joint venture combines parents' services to offer fresh approach to consulting

Heritage expertise allows io oil & gas to treat the field as one system

Sarah Parker Musarra
Editor

In January, McDermott International and GE Oil and Gas formed io oil & gas consulting, a joint venture that looks to offer a holistic approach in developing front-end solutions for offshore fields.

The London-based venture, which plans to expand into the US and Asia, says it will approach the full-field development as one system. That business tenet is immediately evident in glancing through the scope of work the company offers: Services range from portfolio evaluation all the way to the final investment decision: including exploration and planning support, appraisal and feasibility, conceptual engineering and front-end engineering and design.

io oil & gas said it expects to “overhaul” the operator and contractor relationship through leveraging the broad range of expertise offered by its parent companies. However, even with the two company’s products, expertise, resources, and technology at io’s behest, the new company said it will operate independently of its heritage companies.

Strong parenting

Engineering, procurement, construction and installation (EPCI) company McDermott is involved with some of the most high-profile projects in the offshore industry. The company is currently undertaking EPCI services for the complex subsea development offshore Australia for the INPEX Ichthys Gas Condensate SURF project. In the Gulf of Mexico, McDermott is providing EPC services for the Julia Phase I development, including the development’s subsea tieback.

It was also granted contracts for the subsea systems in the Jack and St. Malo complex, and provided subsea systems on the Macedon and Gorgon projects, among others. Last year, McDermott delivered the first TLP offshore Brazil for Petrobras, with its joint venture company FloaTEC and Keppel FELS. The project will enter the record books as the first use of dry-tree floating technology offshore Brazil and the first TLP installation offshore South America.



Left: Dan Jackson, CEO of the newly formed io oil & gas consulting. Photos courtesy io oil & gas consulting. (Photos courtesy io oil & gas)

Above: The leadership team of io oil & gas consulting.

As of late, McDermott seems to be gradually ramping up its subsea offerings, beginning in January 2015 when it announced the io oil & gas consulting venture with GE Oil & Gas.

In February, McDermott announced an alliance with Petrofac to enable the joint pursuit of deepwater SURF projects, bolstering its efforts to expand its subsea offering.

To that end, the depth of GE Oil & Gas’ expertise in the area has made the company nearly synonymous with subsea technology. Drawing on its previous industry experience in related fields such as space and aeronautics, GE has rapidly increased its oil and gas market share.

Through the io oil & gas consulting joint venture, McDermott and GE Oil & Gas stand to provide each other with complementary service offerings – all to the benefit of the operators and customers, who, io CEO Dan Jackson said, will receive greater certainty of costs and schedule along with the enhanced service offerings.

The io approach

Increasingly complex projects residing farther off coastlines and in deeper waters are redefining what operators and contractors consider technically and monetarily feasible. As easy oil becomes played out, such remote, technically-challenging projects are gradually shifting from rarities to the next frontier in development. As a result, contractors’ areas of specialty are becoming more segmented and more specialized from discovery to sanction and everything in between.

At the same time that companies are trying to establish market share hold in specialized areas, interestingly, io oil & gas’ business model calls for it to offer expertise and technology in as many areas as possible. It intends to become a “one-stop shop.” It does not purport to offer one solution, but many; operating as intended, customers could ostensibly be shuttled along each stage of the process in-house, with io oil & gas offering the closest thing to a turnkey solution possible in dealing with such a long and complex series of phases.

According to its mission statement, the young joint venture aims “to deliver greater certainty into the design and planning of offshore oil and gas developments.”

Offshore recently had the opportunity to talk with Jackson, who has been with McDermott since the Houston-based company acquired his 13-year-old consultancy business in 2013. Previously, Jackson served as a project manager and offshore construction manager for Saipem and its joint venture enterprise European Marine Contractors before setting up his global specialist subsea engineering consultancy. He has worked in Europe, the Middle East, Asia, North and South America.

Offshore: Take *Offshore* behind some of the events or discussions that led to the formation of io oil & gas consulting and its core service line. What were the key trends that led to this new venture?

“We are developing an approach that reviews all variables of systems engineering, their influence on the operating strategy and project objectives.”

Jackson: The offshore industry is plagued with inefficiencies and challenges including finding acceptable design concepts, cost discrepancies, and schedule delays.

With volatile oil pricing, this is a turbulent time for the industry. But even in the face of these challenges, working practices have stagnated. The existing model of contracting is piecemeal with specialist designers, contractors, and project managers coming on board one at a time, with no one group that brings the whole project together at the front end to deliver efficiencies and control that should be standard in an ever-evolving offshore sector.

Offshore: What gaps in the marketplace is the new venture looking to serve?

Jackson: Currently, there is no consultancy in the offshore sector offering complete end-to-end services. io has expertise across the entire value chain and offers technical, financial, operational, and business consultancy services all under one roof.

We provide customers with a holistic approach to development, encompassing all aspects of subsurface, subsea and topside design components that will allow for both time and cost savings. We also give the impartial advice that operators are seeking while benefiting from access to specialist resources to assist in technical and commercial projects.

io acts as a full-project architect rather than

just an engineer to effectively manage projects up to the point where investment decisions are made. By becoming fully integrated within an organization, io can ensure that all parties are fully aligned to deliver on time and on budget. It also allows io to inject fresh thinking and insights, balanced with proven and more standardized approaches, to deliver optimum results.

Offshore: Where do you see the most opportunity for io oil & gas consulting?

Jackson: The reverberations of the current oil price are being felt around the globe. There is a noticeable shift in the mindset of the offshore sector, as on-going news of numerous job cuts and project cancellations demonstrates. This is where io has the opportunity to make a real difference and highlight the advantages and efficiencies offered by a holistic systems approach. Contracting relationships are currently fragmented which is holding the

sector back, and has made active permanent changes to the pre-sanction project phase difficult to achieve.

io's true value is seen in creating full end-to-end project models in more extreme environments, such as ultra-deepwater, subsalt and high pressure/high temperature fields.

Offshore: Describe how io offers an end-to-end solution not previously offered.

Jackson: io's offering can be compared to a train transportation system. Here, the manufacturer of the train is just one of the components. Even with a top-of-the-line locomotive, you need the tracks, ticketing and signaling systems, amongst others, to ensure the whole infrastructure runs smoothly. If the track signaling system is two years late, nobody travels on the train – you lose revenue for two years and your economic model is at a standstill. It's the same in the offshore arena – if a subsea floater is late, you can't connect the subsea equipment, and nothing flows.

io represents all of the components of a full system in an integrated manner that can oversee all aspects of an offshore project to ensure definite and cost-effective results.

Offshore: What sectors of the industry stand to benefit the most from io and why?

Jackson: io aims to benefit the whole offshore supply chain as a one-stop-shop for ma-

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In today's market, two out of three major projects overrun on price and schedule. In the offshore sector more than any, time is money and any deviation from a set schedule means more cost incurred by the operator, which can run from hundreds of millions of dollars into the billions.

io helps operators take a project through to the final investment decision, including the planning, front-end engineering and design stages by providing full system solutions and integrating a segregated, possibly fragmented, supply chain.

Offshore: What do GE Oil & Gas and McDermott each bring to the venture, respectively?

Jackson: Both parent companies have unique skill sets that, when partnered with the powerful thinking and staff expertise of io, will allow for greater certainty within offshore projects. The combined knowledge and specialist expertise of over 90 years of heritage of McDermott and the phenomenal technical and commercial strength of GE Oil & Gas enables io to deliver greater certainty, efficiency, and insight into offshore projects.

As a world leader in advanced technologies and services, GE Oil & Gas brings strength in subsea productions systems that allows us to be on the cutting edge in production equipment that we bring to projects. McDermott's engineering, procurement, construction and installation (EPIC) capabilities allow the knowledge and to design and deliver full-field solutions to the industry.

Offshore: How do the two parent companies' strengths complement each other in this independent venture?

Jackson: The legacies and expertise of the parent companies put io in excellent standing to deliver certainty and concrete results in all projects.

In addition to the knowledge and experience of our parents, we pride ourselves on our team's ability to think powerfully. We realize that many offshore problems require out-of-the-box thinking and will benefit from having people outside of the offshore sector. We are committed to hiring top talent irrespective of what sector these individuals have been trained in. We value behaviors and mindsets as much as experience, and are building a team that can deliver a fresh perspective and agile problem-solving.

Offshore: Although it is an independent venture, how could io help bolster the parent companies' business lines, e.g. subsea engineering and construction for GE?

Jackson: Through io, GE and McDermott are joining forces to help operators in this front-end arena. Ultimately, the industry will see the formation of a large-scale end-to-end consultancy, but the bigger prize for the parents is certainty in the market, more successful investment decisions, and overall confidence being returned to operators.

Offshore: What opportunities do you see in today's marketplace?

Jackson: Currently, there is an opportunity for a step-change in applying a systems approach for offshore developments. As deepwater production is in advancing stages, the development of a new way of working is paramount.

We are developing an approach that reviews all variables of systems engineering, their influence on the operating strategy, and project objectives. This approach should be applied as early as conceptual and definition project stages to ensure economic and operational considerations are woven into an entire project. Recent technological achievements including longer tiebacks and advancements in artificial lift require specific methodology to achieve cost-effective field development planning and execution. ●

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Opportunities still beckon for investors of all sizes offshore Africa

Jeremy Beckman
Editor, Europe

Operators off West Africa should revise their goals to suit changing market conditions, according to speakers at the Institute of Petroleum's recent IP Week 2015 conference in London.

Ramin Lakani, Halliburton's regional general manager, said there was an improved climate of political stability across the region. "The nervousness around West Africa some years ago is not there now, with no major conflicts, and statistics show that in 2011, 11 of the world's top 50 improving economies were in Africa. That generates a lot of local demand for power and energy."

Lakani pointed out that in West Africa increasingly, and particularly Nigeria, operators can rely on a local skills base, an important consideration when planning new projects. East Africa is moving in that direction too, he added, although it will take time.

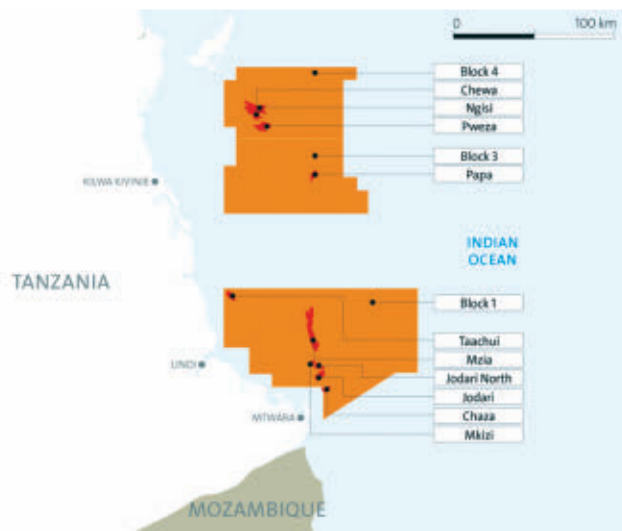
"Throughout West Africa there are still opportunities for every type of player," he continued. "There are plenty of mature fields. In a volatile price environment, these fields provide a strong base, and although they are not as sexy as big deepwater developments, people will pay attention to them." Opportunities to scale up production from pilot projects are also generating interest, he added, while for the bigger players the deepwater hotspots are continuing to draw.

Compared to other mature basins elsewhere, West Africa remains relatively underdeveloped, he claimed, with potential for new exploration plays such as the ultra-deepwater subsalt offshore Angola. The general euphoria over the initial discovery in this play faded following last year's dry wells, but that is the reality of frontier exploration, Lakani insisted. "It takes time to understand a new basin. In this case, hydrocarbons have been proven, but we still need to unlock the code."

Despite the industry's growing capital constraints, West Africa's national oil companies (NOCs) remain active, with some operating significant volumes of production. It is in their interest to keep their programs going, he said. "Our experience latterly with the NOCs, particularly Nigerian National Petroleum Corp. (NNPC), is a general recognition that they need to be more agile, and have to reduce red tape." IOCs hoping to remain in West Africa in the current climate must accept the need to be there for the long term, he added. "Then they can make money."

"Farther down the scale are the smaller players exploring the lesser known basins and a growing large number of indigenous companies, mainly in Nigeria, with Angola now following suit. And there are countries that are new entrants in production such as Ghana, where the costs are quite high, but there are also prolific discoveries."

Another positive, Lakani noted, was the growing desire among the various players to monetize the region's gas, initially via LNG, and more recently via gas to liquids in Nigeria. "Even so, just under 500 MMcf/d is still being flared off Nigeria, and Angola is not far behind. But there is a general recognition that gas is the way forward, and that it can be harnessed to develop more reservoirs." Now the indigenous companies too are looking at gas, he added, partly in recognition that the easier field opportunities, or "low-hanging fruits" have gone. "They can look to squeeze out more production, but they



Gas discoveries in blocks 1, 3, and 4 offshore Tanzania. (Map courtesy BG Group)

also have to go deeper and hotter."

One of the dilemmas for West African producers is that LNG exports to the US are no longer viable, he said, so the region needs to look for new solutions for gas monetization. "In 15 years, it could be that African power stations will be buying US shale gas." One option might be to exploit West Africa's gas in new ways, he suggested, for instance via conversion to methanol or petrochemicals.

Lakani concluded that there are now more than 50 indigenous E&P companies in Nigeria providing 5-10% of the country's production. "That level can be increased via acquisitions, but at the same time these companies need to become more muscular, and grow their reputation at the top table."

One of the most ambitious is Seplat, which tried to bid earlier this year for fellow independent Afren. Mason Ochenejobo, Seplat's strategy and portfolio adviser, said one barrier to growth was Nigeria's licensing process "which can be tortuous and infrequent. Or you may have a field, but you don't know when you may get the chance to increase your holdings around it. But the government does listen."

Last July, Oando Energy Resources acquired ConocoPhillips' upstream Nigerian interests for \$1.5 billion, the largest transaction to date for any African independent E&P company. The assets include interests in two deepwater blocks. One, operated by ExxonMobil, is in the offshore Niger Delta, close to the Agbami and Bonga fields. The other, operated by Shell, includes the Chota and Bolia discoveries. The deal netted Oando proven offshore reserves of 128 MMboe. Oando now has 500 MMboe of reserves and aims to double its current production eventually to 100,000 b/d.

According to Adetokunbo Akindele, head of corporate development, the Toronto Exchange-listed company had to raise \$500 million to complete the deal. "We found that a lot of people don't want to invest in Nigeria, particularly in non-listed companies" he said, due

in part to perceptions over the Niger Delta disturbances, Boko Haram's insurgency in northern Nigeria, and uncertainty over the country's next elections.

Akindele said African independents looking to raise funds are always asked if they can meet their capex and opex targets. The lower oil price has led some companies to become takeover targets, he said, "particularly those with massive overheads on projects which cannot meet its obligations." It has also impacted local oil service companies. "One contractor has five rigs," he said, "but only one is operating, as no one can afford the rates." But smaller companies specializing in indigenous plays can also produce oil with lower operating costs, Akindele claimed. "They know the area better than the majors, and they know what to do to get the resources to the market."

London-based Ophir Energy has been one of the pioneers of deepwater exploration offshore West and East Africa over the past few years. Dr. Mike Fischer, the company's president-Africa, related how the company bid successfully for deepwater blocks 1, 3, and 4 in the Mafia Deep basin off Tanzania in 2005-06, an area attracting little interest at the time. Initially, the company had just enough in the bank to pay for the license fees and a subsequent seismic survey. Later, it attracted funds to operate wells that brought East Africa's first deepwater discoveries on the Chaza, Pweza, and Chewa gas fields.

In 2009, the company brought BG Group into its three blocks, with the latter operating all wells beginning in 2011. The partnership has now drilled 16 exploratory and appraisal wells, and conducted five drillstem tests, with no dry holes to date. "In addition, our blocks are mostly covered with 3D seismic," Fischer said, "with a lot of 2D data, and we have established a working petroleum system."

To date, the partners have discovered a total of 17 tcf of gas, he added, while Statoil and ExxonMobil have uncovered a similar volume on block 2, sandwiched between blocks 1 and 3. The two consortia are co-operating on a scheme to develop Tanzania and East Africa's first onshore LNG plant to harness the gas.

Getting to this point in an area which had experienced little prior offshore activity and which is prone to raids by pirates involved building strong relationships with Tanzania's government and navy. "We have also had to work with the government to develop production-sharing arrangements in order to monetize the gas," he explained.

Another challenge was the lack of support infrastructure, which meant it was taking too long for vessels to get out of port in Tanzania to support the exploration programs. "We responded by transforming the old port

that handled cashew nuts into a world-class port," Fischer said.

There is pressure throughout Africa's emerging offshore to build local engineering capabilities. "As a 50-strong company, we couldn't take on [the] training of large numbers of Tanzanians," Fischer explained. "But we have worked to do this via our lead service providers. And as the LNG project develops, that is the real opportunity for local employment and training. Our office in Dar es Sa-

laam will be staffed entirely by locals."

Off Africa's west coast, Ophir has discovered sufficient gas in relatively shallow water off Equatorial Guinea for what could be the continent's first floating LNG project. Offshore Gabon, the company has drilled several wells in the deepwater subsalt, attracting Petrobras as a partner. Although there have been no successes to date, "we are gradually understanding how the play works," Fischer said, "and we plan more wells there." ●

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Barbados invites bids for offshore blocks

New seismic reveals potential oil prospects

Peter Abrahamson
MultiClient Geophysical

Jamar White
Division of Energy
and Telecommunications
Government of Barbados

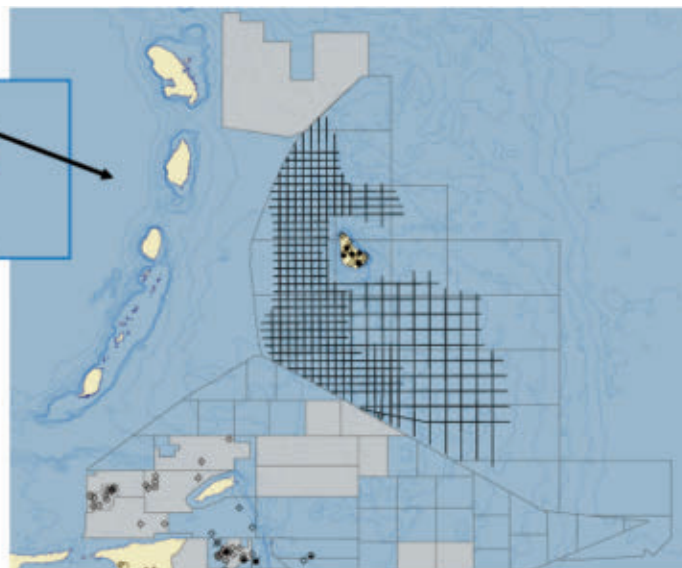
Kenneth Mohn
MultiClient Geophysical

Barbados' government will open large parts of the country's offshore area for bidding during 2015, with favorable terms for international oil companies. All these unlicensed blocks can be considered as a rank wildcat exploration area, and early movers will be able to pick up the best prospects.

MultiClient Geophysical ASA (MCG) acquired a new seismic, gravity, and magnetic multi-client 2D survey offshore Barbados during 2013, which improved subsurface imaging of this highly prospective area. Mapping of the region's Cretaceous La Luna age-equivalent source rock – not previously feasible using the old seismic – is now possible, and the new data has led to identification of more than 20 large oil prospects.

All components for successful exploration

Oil production in Barbados has existed since the beginning of the previous century supporting the Cretaceous La Luna age equivalent source rock connection. (Photos courtesy MultiClient Geophysical)



appear to be present offshore Barbados. Several source rocks can be identified on the new seismic. Basin modeling, derived from the MCG survey, suggests active oil generation and migration. Good sandy reservoirs, likely originating from the Paleo-Orinoco Delta, can be tied into the seismic, containing numerous large structural closures. These structural closures and stratigraphic prospects show many forms of direct hydrocarbon indicators (DHI).

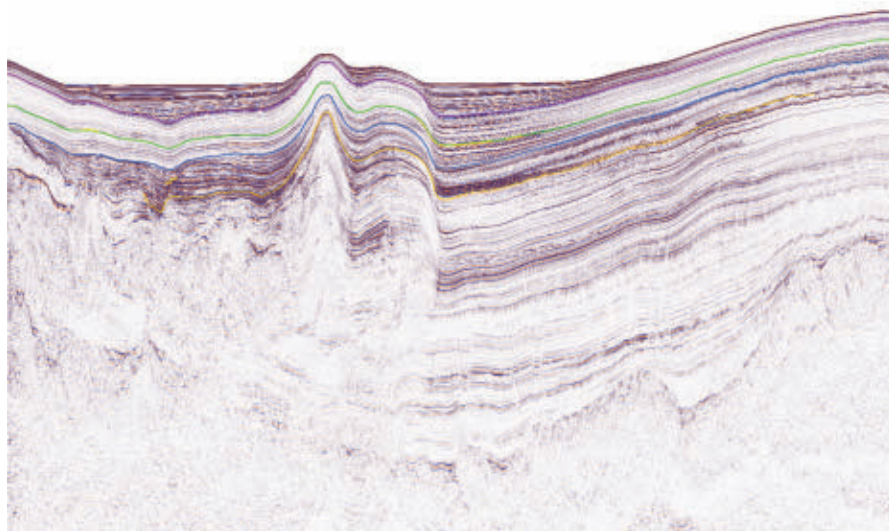
Exploration, production history

Oil production started onshore the island in the early 1900s. The reservoirs consist of Eocene sandstones from the Scotland Group and the sweet, light crude oil is geochemically proven to be generated from the La Luna equivalent source rocks. The producing traps are highly compartmentalized due to the intense and repeated faulting (both compressional and extensional) on the island. This faulting is much less evident in parts of the offshore area.

There has only been one well drilled offshore Barbados. ConocoPhillips, in partnership with Total, drilled the Sandy Lane exploration well in 2002 in the Barbados Trough, targeting a Miocene sandstone in a trap close to a mud diapir with a weak amplitude anomaly in half the structure. The well revealed low concentrations of gas in the reservoir. ConocoPhillips concluded that the trap had probably been breached by faulting. However, the well did prove several high-quality Miocene reservoirs, and these can be tied to the new seismic and correlated into larger structures.

Regional geology and large prospects

During the breakup of the supercontinent Pangea, Barbados was geographically located in the southeast corner of the open



Various source rocks can be identified from the new seismic offshore Barbados.

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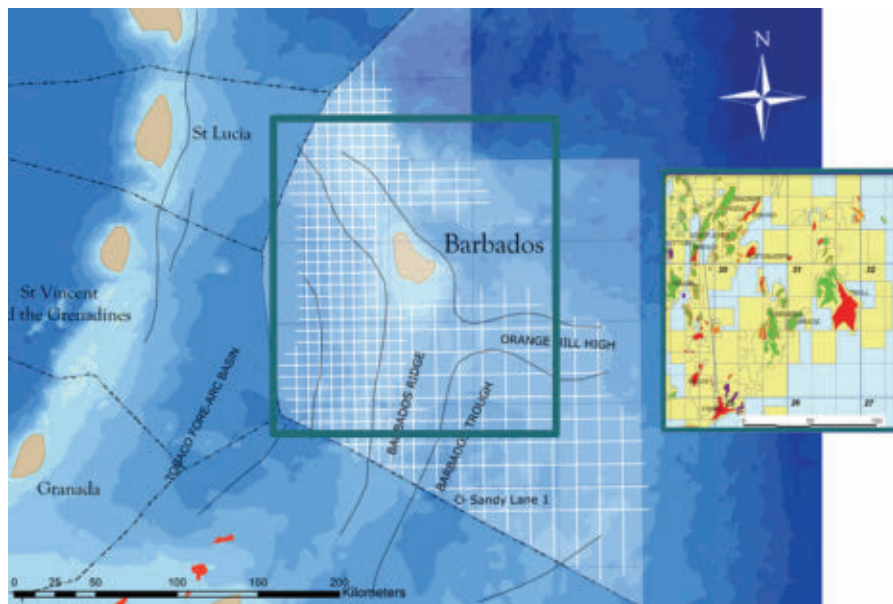
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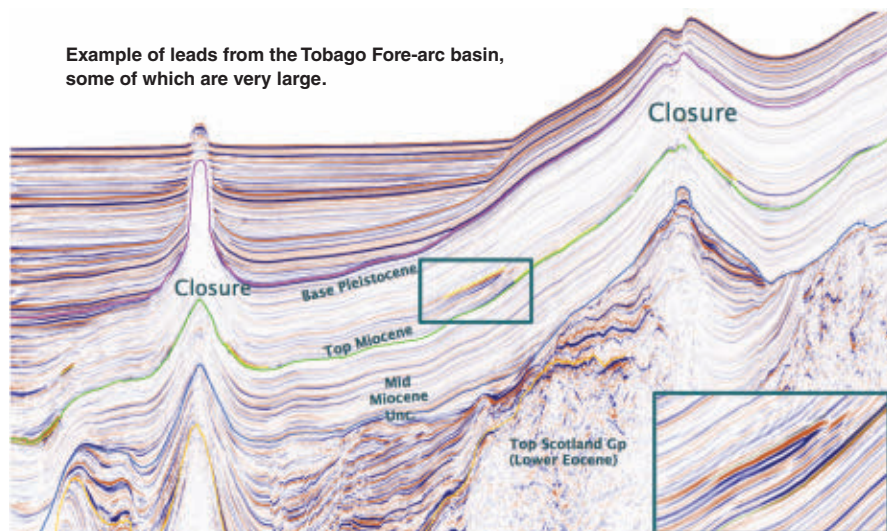
Only one well has been drilled to date offshore Barbados.

North Atlantic basin prior to the opening of the South Atlantic. The area is close to the Orinoco Delta and Trinidad. This region was located in the southeast corner of the opening of a large seaway that extended to the Gulf of Mexico in the Middle Jurassic, roughly 166 million years ago. A late Tertiary collision between plate boundaries around the Caribbean Plate and the Atlantic Plate created a large accretionary ridge that set up the region's current geology.

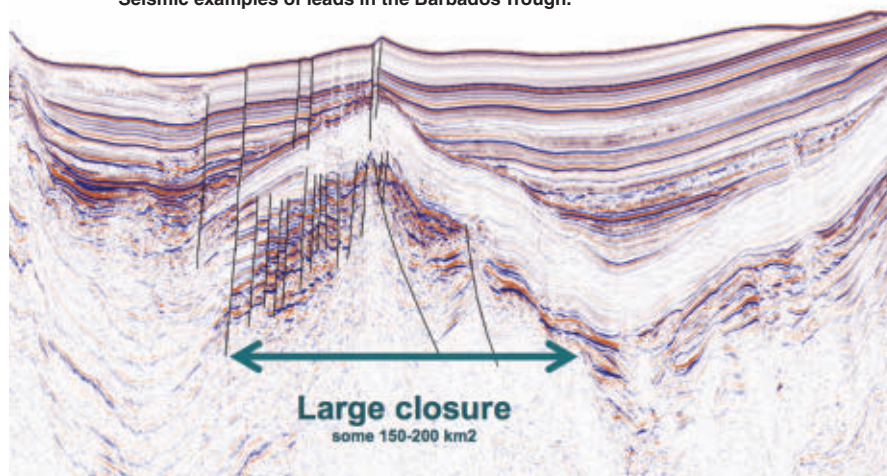
Around 80% of the island of Barbados is covered with Quaternary limestone. On the northeast side of the island, outcrops of older sandstone and clastic rocks, uplifted and deformed by tectonic activity and related diapirism, are visibly stained with oil. Salt basins have yet to be identified but shale



Example of leads from the Tobago Fore-arc basin, some of which are very large.



Seismic examples of leads in the Barbados Trough.



movement and diapirism is prevalent. This is a continuation of the shale diapirs and structures from Trinidad to the south.

The offshore area can be divided in three main geological provinces. The north-south trending Barbados Ridge running up through the island divides the area into a western part known as the Tobago Fore-arc basin and an eastern part named Barbados Trough. Large structures and prospects can be found in many locations.

New bidding approach

In 2007, Barbados launched its first offshore oil and gas licensing round, inviting international oil companies (IOCs) to bid for the right to explore and produce hydrocarbons in the island's offshore acreage. Twenty-four blocks were offered, and from this process, BHP Billiton was awarded two offshore blocks - Carlisle Bay and Bimshire. Since that time, Barbados has continued to attract significant attention from IOCs interested in attaining petroleum rights throughout its offshore territory.

The government's Division of Energy and Telecommunications will launch the new offshore licensing campaign this year, offering select blocks to the industry under a fair and transparent process of direct negotiations.

Despite the current low oil-price environment, Barbados is keen to further exploration of its offshore acreage and will seek to partner with technically strong, financially capable companies that can help the country realize its offshore petroleum potential. Information relating to the application process, pre-qualification criteria, blocks on offer and important deadlines, is available on the division's website. ●

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3D CSEM can play vital role in offshore exploration

Vincent Vieugue
Jason Tinder
EMGS

Data provides operators improved probability of economic success

There is no doubt that seismic data is highly effective in providing operators with structural and stratigraphic information (trap and reservoir potential) as well as volume estimation parameters such as gross rock volumes.

Yet seismic continues to have difficulties in detecting fluid content and the potential hydrocarbon volumes within the reservoir. There is subsequently a danger of operators identifying a prospect with what appears to be strong seismic, amplitude versus offset and geological potential but failing to predict the fluids. With a significant number of wells failing due to uncertainties on fluid content, this is a significant information gap.

It is against this backdrop that 3D controlled source electromagnetic (CSEM) surveys have a vital role to play in the offshore exploration workflow – accurately predicting fluids and field volumes and delivering improved probability of economic success for operators.

Predicting field volumes

3D CSEM surveys map resistive bodies in the subsurface – fluid-driven parameters that correlate strongly with the fluid content and saturation of hydrocarbons where the larger the resistive body, the greater the response.

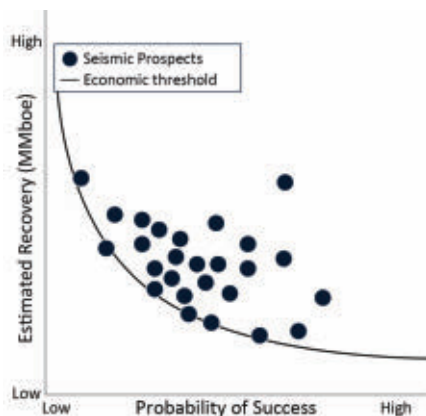
Whereas most prospects generally have higher uncertainty in probability of success to start with based on seismic interpretation alone, adding EM data will enable better fluid predictions.

When trying to optimize and prioritize a portfolio of prospects, 3D CSEM data provides operators with the ability to polarize their portfolio and identify areas with larger hydrocarbon accumulations where they are more likely to be economically viable. This brings with it significant savings in drilling costs as well as ultimately more profitable fields.

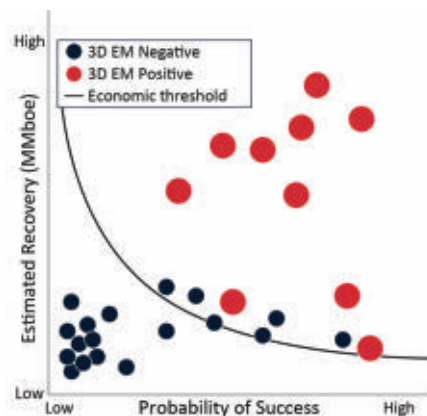
Portfolio polarization

The impact of portfolio prioritization using 3D CSEM can be seen in the seismically derived prospects in the first two graphs.

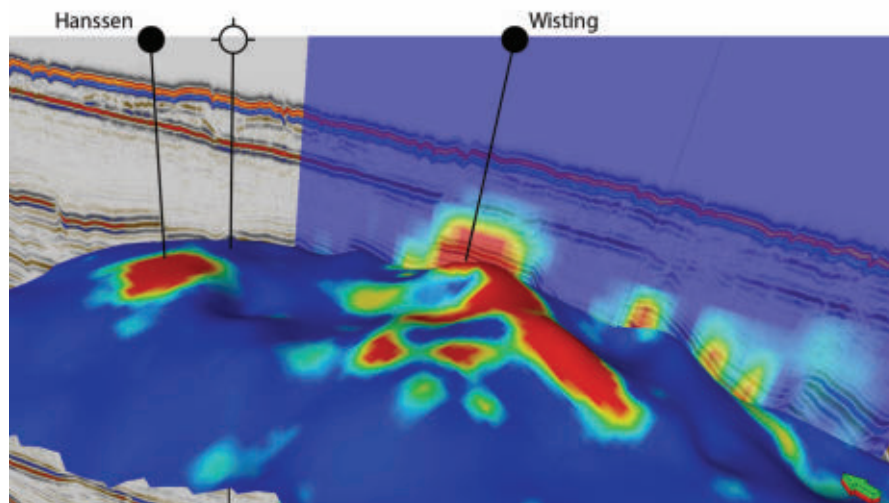
The first represents a portfolio of prospects with the vertical axis representing probability of success and the horizontal axis estimated recovery volumes by a million barrels of



Illustrative example of a portfolio before 3D CSEM. (All images courtesy EMGS)



Illustrative example of a portfolio after 3D CSEM.



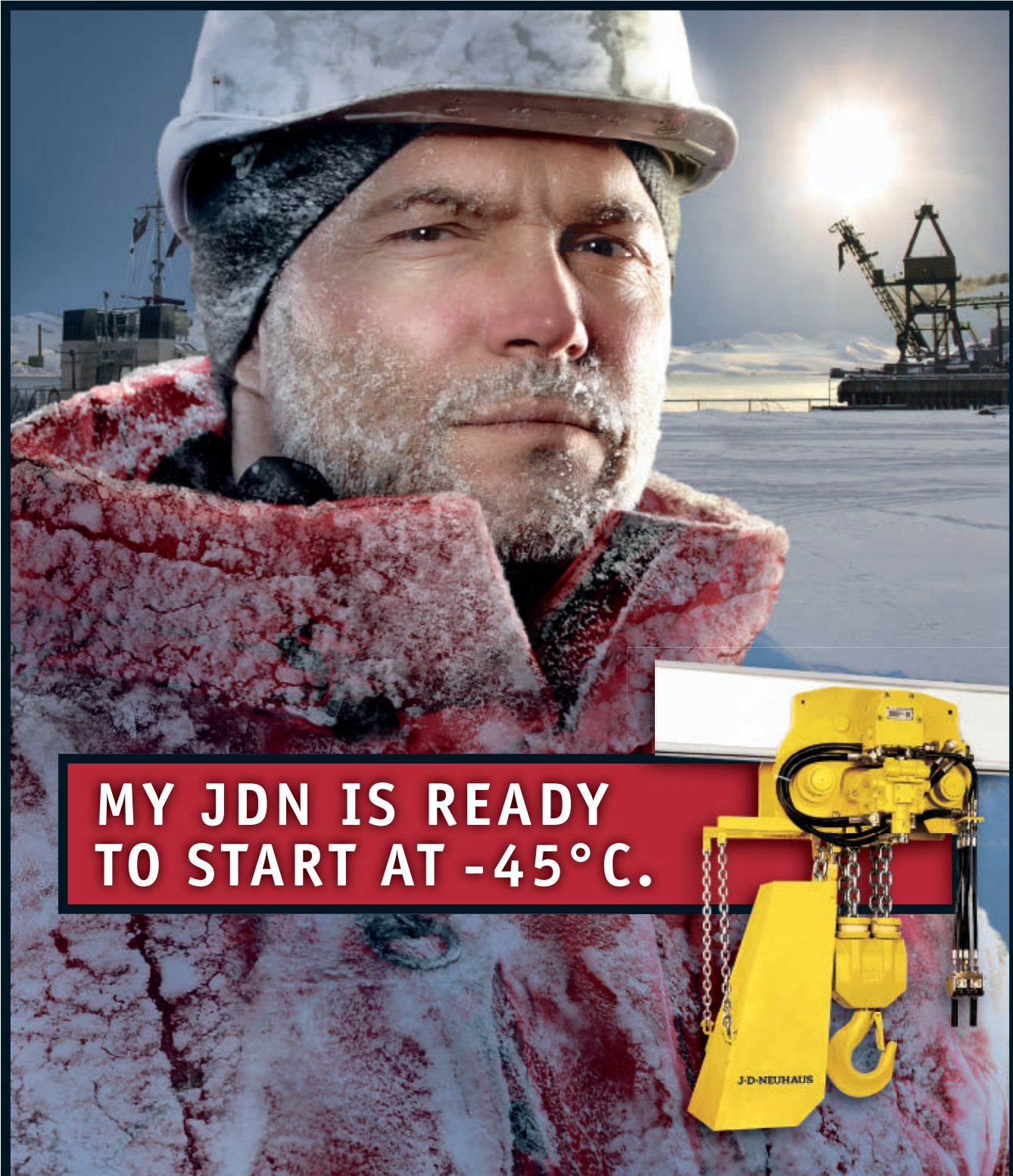
The Wisting and Hanssen oil discoveries are clearly associated with strong resistive anomalies (red areas) from the 3D CSEM data. The well next to Hanssen going through a low resistive area (blue) is dry. (Seismic data courtesy TGS)

oil equivalent (MMboe). The second shows this same portfolio after the application of 3D CSEM where prospects with a resistive anomaly see an improvement in estimated reserves and/or probability of success and the remainder are near the economic threshold or found to be non-commercial.

The theory of portfolio polarization is to high-grade commercial prospects, disqualify non-commercial prospects, and drill high

impact discoveries first. As in this example, the use of 3D CSEM with seismic, petrophysical, and geologic data enhances subsurface understanding by limiting the range of possible geological scenarios.

3D CSEM's sensitivity to net rock volume and pore fluid can result in a significant reduction in uncertainty since prospect area and net pay are associated with the highest uncertainties in reserves estimation, espe-



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Resistivity map from the Alaminos Canyon area.

cially in frontier exploration areas. This dramatic difference in portfolios leads to a better classification of prospects through the downgrading or upgrading of the probability of finding hydrocarbons, and an improvement in the evaluation of the size of the accumulation.

CSEM surveys in the Barents Sea

EMGS has been commercially acquiring CSEM surveys for more than 12 years in many of the world's basins, with the last five years seeing a mature, well developed technology used with confidence, leading to better exploration decisions and improved investment returns.

One such example is in the Barents Sea, a vast under-explored area, exhibiting a large variety of geological settings and offering significant hydrocarbon potential as indicated by a working, hydrocarbon migration pathway.

To date, however, 28 exploration wells have been drilled in the area and yet only nine have proved to be commercially viable. In all nine cases, EM anomalies and resistivity were identified and in all other cases there was low or no EM responses.

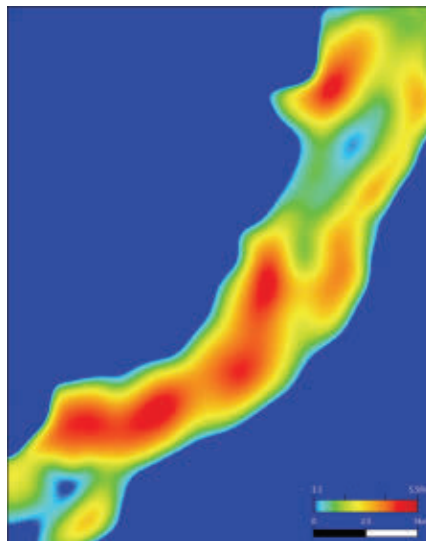
For example, in well 7324/7-2 on the Hanssen structure drilled in June 2014, an EM anomaly was coincident with the discovery and resembled the nearby Wisting discovery. The 3D CSEM survey results found the largest EM anomaly in the area related to the Wisting Central structure with estimates of 132 MMboe and the second largest anomaly related to the Hanssen discovery where 18 to 56 MMboe were detected. This latter anomaly was approximately a quarter of the size of Wisting and fitted exactly with the size of proven reserves.

In the case of the nearby Mercury well, there was an apparent EM anomaly associated with the prospect but the strength of the anomaly was only one-third of that of the Hanssen prospect and subsequently delivered much smaller volumes at 6-12 MMboe. This again demonstrated a strong correlation between the observed anomaly and the hydrocarbons discovery in the area.

CSEM surveys in the Gulf of Mexico

EMGS also has recently completed the 4,100-sq km (1,583-sq mi) Daybreak 3D CSEM survey in the Alaminos Canyon area of the US Gulf of Mexico.

In one part of the survey in the Great White field around the Perdido installation, the survey dropped 130 receivers and towed



702 km (436 mi) of source lines in water depths varying from 1,700 to 3,000 m (5,577 to 9,842 ft). Receiver nodes free fell into position (with all dropped within specification and 88% within 100 m of their planned location). The source was towed 30 m (98 ft) above the seafloor to transmit an EM signal into the subsurface.

Using the integrated interpretation of 3D CSEM (as seen in the resistivity map) and seismic data has been a valuable tool for several companies participating in the Western Gulf of Mexico Lease Sale 238 with 14 operators submitting 93 bids in August 2014. The 3D CSEM and seismic data will also continue to play a key role in Lease Sale 246, acquisition and divestiture decisions, and well placements in the area.

The company also has extensive experience across the border in Mexico with several published case studies. The opening of Mexican offshore exploration will see several companies using the integrated interpretation of 3D CSEM and seismic data to inform leasing decisions.

Meeting other offshore challenges

There are a number of specific characteristics of offshore fields that 3D CSEM surveys are particularly well suited to. For example, delineation wells are extremely common as a means of measuring the shape of the field, fixing the boundary of the field for greater accuracy, and for well calibration.

3D CSEM surveys with horizontal resolution, strong calibration points, sensitivity to the edges of the reservoir, and the ability to measure the reservoir's lateral extent limit the need for such delineation wells. With drilling expenditure for field appraisal the largest single expense in exploration, this leads to significant cost savings and places EM as an im-

portant direct hydrocarbon indicator (DHI).

Similarly, there are many areas of the world where seismic data is often severely compromised, due to multiples in the area with amplitudes greater than the primary reflections and significant issues with depth conversion.

Prospective salt and basalt provinces also present a huge challenge to seismic's ability to image below or adjacent to such hard lithology. The fact that seismic struggles to properly position the base of salt or basalt due to refraction and scatter makes it difficult to build an effective velocity model, which is critical to imaging capability.

In such cases, 3D CSEM surveys can play a key role in complementing seismic and providing an independent, highly reliable geological measurement that supports seismic data.

EM measures and is subsequently unperturbed by the scatter and refraction that causes seismic such difficulties and can affect velocity models. In salt and basalt provinces, the base of the salt/basalt can be accurately derived by CSEM surveys through the change in resistance and then applied to the velocity model to improve the quality of the migrated seismic image.

EM's structural imaging capabilities have been applied to some of the world's most difficult to image salt and basalt areas, such as the Gulf of Mexico, Brazil, west of Shetland, and the Red Sea.

Exploration workflow

3D CSEM surveys and data have an important place in the exploration workflow, working with seismic, petrophysical, and geologic data to develop a geological model as close to reality as possible.

Understanding that it is not always easy to bring new measurements into already robust workflows, EMGS has developed workflows and tools that can be used by operators to quickly and accurately assess the sensitivity of their prospects to EM and quantify volumes.

3D CSEM results can be incorporated into the exploration workflow and integrated with seismic and well log data to support both area net thickness, and the probability of success from structural and stratigraphic information.

Changing the exploration landscape

While seismic is a given in offshore exploration, it is only by accessing a variety of different data sources and technologies that a complete picture of the subsurface and its economic potential and risk can be developed.

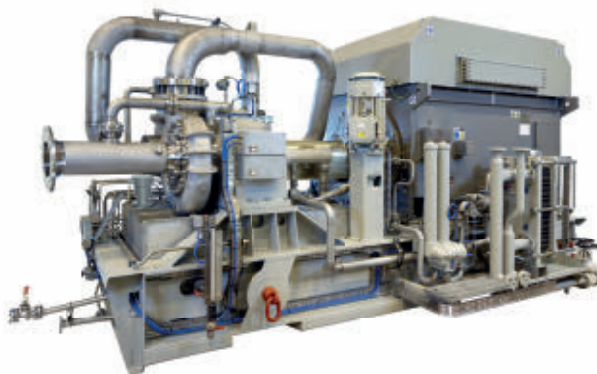
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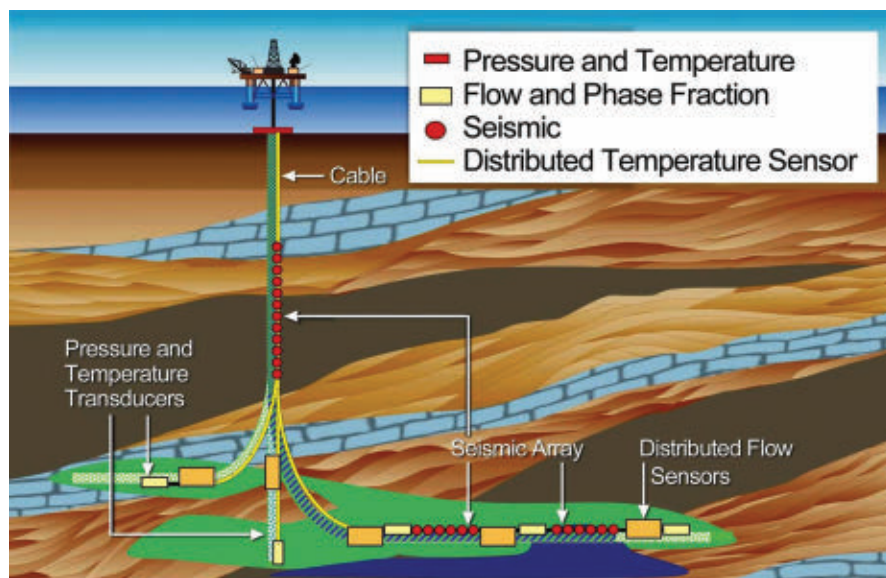
Rajan Chokshi
Weatherford

Whether operating in greenfield or brownfield environments, it is essential for oil and gas producers to obtain an accurate assessment of each asset's production capability. This enables them to develop prudent reservoir management and practical production strategies related to artificial lift, flow assurance, monitoring of installation integrity, and QHSSE. Also, as production activities move to more challenging locations like deepwater, subsea, and high-pressure/high-temperature (HP/HT) environments, the stakes become higher, making key production information even more valuable.

Conventionally, well test measurements, coupled with production logging and wellbore gradient surveys, have been used to assess the productive capabilities of a well. However, the frequency of such data captures is inadequate to address the dynamic production changes that are common in offshore installations. A related challenge is the lack of synchrony among these data sets, which often leads to inaccurate predictions of production behavior. This, in turn, can result in delayed, wrong, and often expensive intervention decisions.

A better solution to protect high-value investments in offshore and subsea installations is to take a proactive approach, using real-time downhole, subsea, and surface measurements to monitor and analyze well performance. This enables operators to curtail performance deterioration and deter imminent failure of downhole artificial lift equipment, as well as to tailor preemptive responses to potentially unsafe conditions such as hydrate, asphaltene, or wax precipitation.

Rather than wait until well tests or other symptom-discovery tests are conducted, reservoir managers would prefer to receive immediate information about changes like water breakthroughs or production response to secondary or tertiary recovery approaches. Having access to a well's downhole pulse—in the form of real-time downhole pressure and temperature readings, surface or downhole flow rates, and even water-cut measure-



Downhole sensing capabilities. (Images courtesy Weatherford)

ments—is invaluable in performance- and compliance-conscious environments.

Different approaches

Today, subsurface technologies enable real-time production surveillance for pressure, temperature, flow, and vibration measurements. On top of that, recent advances in flow technologies permit measurement of water cut, as well as flow rates at wellheads or near central processing sites with partial or no separation. Such capabilities are especially useful in offshore environments, where valuable deck space that is typically allotted to expansive separation facilities could be saved by using inline, no-separation measurement technologies. A recent entry in this space enables real-time water-cut measurement in the production stream from a subsea well. Whether obtained from subsurface or surface instruments, measured data transmits telemetrically to a process platform en route to a shore-based field office or corporate location.

Subsurface measurements

Subsurface measurement technologies can be classified into two broad categories: electronics-based and fiber optics-based.

Electronics-based technologies are used for routine applications with moderate tem-

perature and pressure ranges. These high-volume, economical gauges are used extensively for pressure, temperature, and vibration measurements in artificial lift monitoring, producer and injection well surveillance, and zonal production management applications. In artificial lift applications, the ability to combine the pump intake and discharge pressures with vibration data enables a continuous health check of equipment—in addition to proactive lift adjustments—so that equipment deliverability is matched closely to reservoir capability. Proactive lift management avoids underutilizing equipment by making adjustments to ensure that lift volume corresponds adequately with available, safe reservoir volumes. Conversely, it also aims to avoid lift equipment damage that can result from using incorrect settings or oversized equipment and outrunning reservoir deliverability. Recent developments in quartz-based technology enable sensing at higher pressures and temperatures with better resolutions, higher-frequency data updates, and up to 16 sensing locations on a single conductor cable.

Fiber optics-based downhole sensing technologies have been in use for more than two decades, and they have proven their value while providing improved reliability. Distributed temperature sensing (DTS) using fiber optics is a well-known application,

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Deck space required by a separator system, compared to a multi-phase flow meter.

but distributed acoustic sensing (DAS) is another emerging technology in this area. However, the availability of robust, reliable point and multi-point sensors for pressure, temperature, flow, and seismic measurements has expanded possibilities considerably. Optical cable, which typically contains three or four fibers, can combine multiple measurements in the same cable and even in the same fiber. This capability opens up a wide range of permanent downhole sensing possibilities in a single well, on a single cable.

DTS and array temperature sensing (ATS) point sensors each have advantages and disadvantages. For example, DTS allows spatial coverage over the entire length of a fiber-optic cable, but with a slower update rate and greater susceptibility to optical losses. ATS capabilities provide robust measurements up to ultra-high temperatures—even in the presence of higher optical losses—while delivering higher resolution and better stability with faster updates than DTS, but spatial coverage can be more limited.

Combinations of ATS and DTS are now available and can, in some cases, provide the optimal downhole temperature profiling and monitoring solution.

Fiber optics-based downhole flow measurement technology opens up unique possibilities, particularly for determining accurate allocation of multiple-zone production or injection. One notable feature of this nonintrusive technology is the bidirectional measurement capability for single- and two-phase flow measurements.

Surface measurements

Water cut is a key performance indicator for any well. Traditionally, this has been determined during periodic production well testing, but now this key performance indicator can be monitored continuously at the wellhead using near-infrared spectroscopy based water-cut measurement systems. These can be used on any multi-phase line, either topsides or subsea. They can be used for sensitive water onset detection and subsequent tracking of water production throughout the life of the well. They also provide the critical water-cut measurement role in modular multi-phase flow meters. The near-infrared sensor technology provides the most sensitive water detection technique available and is indifferent to salinity or water chemistry.

Multi-phase and wet gas flow meters provide oil, water, and gas flow rate measurements without the need for separation. That means a small footprint, which makes these meters ideal for offshore platforms where deck space is very expensive. Additionally, the meters deliver significant capex savings over the cost of a conventional three-phase test separator, especially for high-pressure and corrosive process stream applications. They are also easier to service compared to conventional separators, and have built-in diagnostics to track performance and alert operators as soon as a problem occurs. Safety is also improved by eliminating the test separator, and the associated volume of pressurized combustible hydrocarbons.

Converting data into information

All the above measurement devices sense data in real time, generating significant data streams. For reference, traditional applications that measure downhole pressure, temperature, and flow rate typically generate data streams in ranges of kilobytes to megabytes per day, per well. DTS applications, on the other hand, generate up to a gigabyte of information, and DAS tips the data scale in the terabyte range. These data volumes create significant challenges for conventional analysts, who typically handle a few point measurements for each well on a weekly or fortnightly basis. Traditionally, data analysis for lift or reservoir management occurs using standalone software packages.

The promise of multi-stream, real-time measurements to improve reliability, safety, and environmental performance can be realized only with continuous analysis of high-frequency data. This approach begins with a full system that is capable of multi-dimensional visualization. For example, simultaneous visualization of DTS and downhole pressure data provides quantitative estimation of reservoir influx, whereas simple DTS visualization provides qualitative estimation of influx. Once data is processed through the visualization phase, relevant data slices must be parsed and routed to software packages for lift analysis or reservoir test analysis.

By combining real-time downhole, subsea, and surface measurements with powerful data management capabilities, proactive monitoring is quickly becoming recognized as an affordable, efficient, and leading-edge production solution for offshore environments.

Case studies

An offshore platform operator in Alaska's Cook Inlet needed an onboard test facility to provide regulatory allocation measurements and support production optimization efforts. With no process separation or production measurement equipment on board, well flow had to be directed to a land-based facility 5 mi (8 km) away. To improve efficiency and quality of measurements in these tight quarters, the operator installed a compact multi-phase flow meter. The installation required no expensive modifications to the platform, and there was no interruption to day-to-day operations. The operator now receives accurate and repeatable flow rate measurements with short test times because there are no purge times. This results in more tests for each well and highly accurate production tracking.

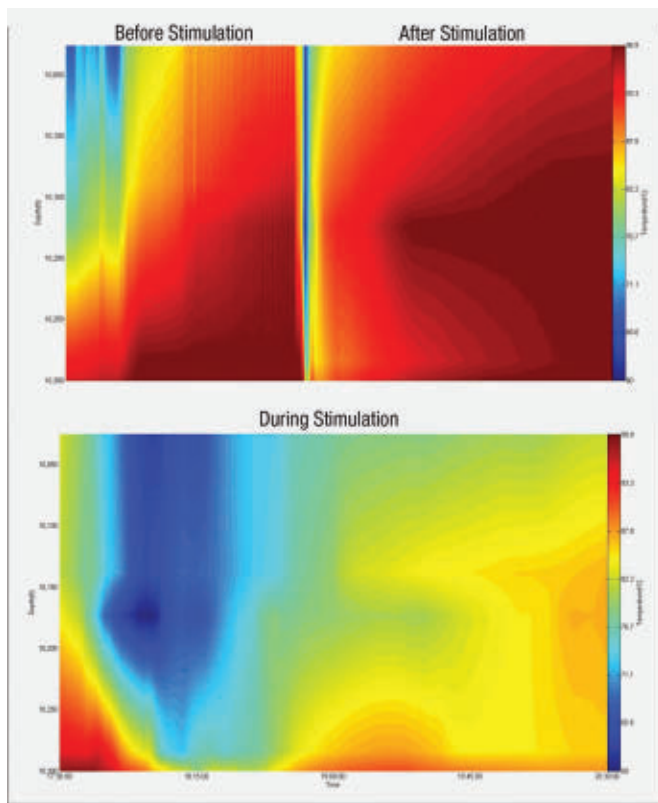
Visible benefits

For a newly developed field in the North Sea, a major independent operator installed multiple in-well sensors and collected initial results for the first 13 well completions. To meet a full array of downhole-monitoring and production-analysis objectives, the operator decided to monitor each well with a permanent downhole monitoring system (PDMS), including a pressure/temperature sensor, a full bore, two-phase flow meter, and a DTS monitoring system.

This all-optical reservoir monitoring system, installed on a single fiber-optic cable in each well, enabled effective real-time observation and management of reservoir parameters and lift performance, as well as completion integrity over the life of the field. These PDMS installations reduced well test times for the operator, improved production allocation across the field, and eliminated workover costs associated with typical pressure/temperature surveys—while providing highly accurate input for planned buildups or unplanned shut-downs.

Flexible, bidirectional monitoring

A North Sea operator chose to enhance production by converting a production well (producer) to a water-injection well (injector). The well was already equipped with a fiber optics-based PDMS to mea-



Real-time temperature monitoring, before and after stimulation treatment.

sure pressure, temperature, flow rate, and distributed temperature. To better manage the injection process, it was critical to determine the injected-fluid flow rates, since small fluctuations could have significant impact on oil production economics. The optical flow meter in place was ideally suited to the task.

Due to the true bidirectional measuring capability of the in-well optical flow meter, the conversion from producer to injector required no hardware or software changes to the flow meter or surface instrumentation. The flexibility of the PDMS resulted in a reduced initial equipment investment and significant time savings, with no need to install additional measurement equipment. Optical multi-phase flow meter installations are equally capable for bidirectional flow measurement of either oil or gas.

Stimulation for improved production

An operator in the Gulf of Mexico had installed permanent down-hole gauges (PDHG) in several wells to measure pressure, temperature, and distributed temperature. With one of these wells, these pressure and temperature sensors provided a real-time indication of significant slugging, as well as liquid production only from the lower zone. This prompted the operator to apply a corrective stimulation treatment, which resulted in stabilized, much higher production from the middle zone. Without downhole measurements, such rapid reservoir management response would not have been possible. In addition, such real-time measurements enable precise placement and monitoring of stimulation treatment. PDHG real-time monitoring systems allow a much more detailed understanding of reservoir production trends, the stimulation process, and post-treatment effectiveness. ●



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Feasibility study assesses two dry tree options for the Gulf of Mexico

Research examines drilling/production solutions in 8,000-ft-plus waters

Roy Long

*National Energy Technology Laboratory,
US Department of Energy*

Operators in the Gulf of Mexico (GoM) are increasingly looking to ultra-deepwater (>5,000-ft-1,524 m water depth) fields and more challenging reservoirs to deliver the hydrocarbons that the energy market demands and to satisfy their production growth objectives.

These deep subsalt reservoirs frequently have complicated issues, including additional required drilling, more complex completions, artificial lift requirements, and workover/intervention complexity.

These issues point to the use of dry trees as the most economical solution. In many cases, the depth of the reservoir requires a large drilling rig and drilling variable payload, resulting in very large topsides which challenge the limits of current spar technology.

Project overview

DNV GL was granted an award by the Research Partnership to Secure Energy for America (RPSEA), partially funded by the US Department of Energy's National Energy Technology Laboratory, to manage a project to develop dry tree semi concepts for the ultra-deepwater fields in the GoM. DNV GL's role in this project was twofold:

- To manage, on behalf of RPSEA, further development of two semisubmersible concepts suitable for drilling and production in the GoM ultra-deepwater, using dry trees.
- To act as an independent third-party verification agent for assessing the maturity of all safety and environmentally critical aspects of the concepts so that they are "project-ready" in the Gulf of Mexico.

Under the aegis of this project, two previously developed dry tree semisubmersible concepts were further matured for operation at 8,000-ft (2,438 m) water depth in the GoM:

- Paired Column (PC) semisubmersible developed by Houston Offshore Engineering (HOE)
- Deepwater Dry Tree Semisubmersible (DWDTS) developed by Kvaerner Field Development (KFD).

Both concepts had previously gone through some development (i.e., previous RPSEA funded projects, DeepStar funded projects, etc.). The current RPSEA project focused on critical design elements identified in the earlier work. In evaluating the designs, DNV GL endeavored to ensure that both concepts were developed in accordance with the same design basis. Of course, each design has its own unique chal-

lenges, which have been the focus of DNV GL's evaluation.

In previous projects, the following elements were identified as the most critical issues for each concept:

- Vortex-induced motion (VIM) and quayside integration for the HOE PC semi concept
- Riser tensioner qualification for the Kvaerner DWDTS concept.

Both concepts underwent VIM model tests and extensive engineering work. DNV GL conducted AIP evaluations for both concepts and TQ for each riser tensioning system. DNV GL concluded that the above critical elements have been adequately addressed for the purposes of conceptual design. Therefore both concepts are considered feasible, and can be regarded as "project ready," provided all comments and suggested actions in this report are properly addressed in the next project phase (e.g. FEED).

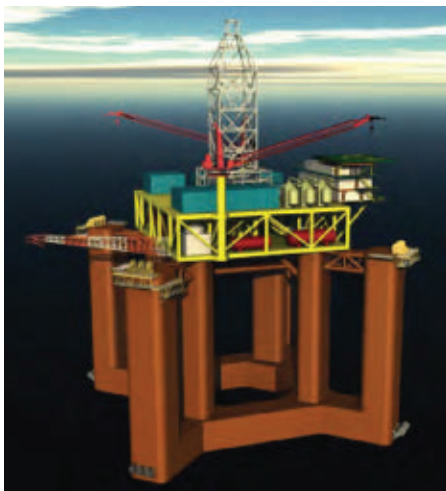
This project involved a large number of subject matter specialists from the industry and from DNV GL in key steps during design basis assessment, progress review, model tests, and final Conceptual Hazard Identification (HAZID) workshops. Throughout the project, the objectives have been to ensure that the concepts (1) are in line with industry practice and (2) meet the requirements for safe operation in the GoM. The discussion that follows is an update on this project, completed in December 2014 and originally discussed in *Offshore* in June 2012.

Dry trees for the Gulf

GoM dry tree solutions have been dominated by spars and tension leg platforms (TLPs). For water depths beyond about 6,000 ft (1,828 m), the TLP typically becomes cost prohibitive. For large payload systems, especially those requiring large drilling payload, the spar size, transportation options, and offshore installation become a challenge. The semisubmersible vessel offers several advantages over the spar option, including larger deck space and the possibility

of quayside topsides installation and integration. It is expected that the dry tree semi will be cost competitive with the spar in most cases and will overcome the size limitations of the spar option.

The industry has shown significant interest in developing a dry tree semi solution over the last few years to increase contracting options. However, there remains an uncertainty about the total system maturity, constructability, performance, and cost efficiency. So far no dry tree semi has been selected as a host platform for large payload systems in ultra-deepwater.



Paired Column semisubmersible concept by Houston Offshore Engineering (HOE). (Image courtesy HOE)

Q&A

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Key design data for HOE PC semi.

Design Cases		Maximum Riser Config. (1DR+11TTRs + 17 SCR's)	Minimum Riser Config. (1 DR+1 TTR +3 SCR's)
Draft	(ft)	175.0	
Displacement	(kips)	220,056	
Water Depth	(ft)	8,000	
Number of Inner Columns		4	
Inner Column Height	(ft)	244.0	
Inner Column freeboard height	(ft)	69.0	
Inner Column Side Length	(ft)	34 x 46	
Inner Column c/c Span	(ft)	165	
Numbers of main pontoon		4	
Main Pontoon Width	(ft)	42.0	
Main Pontoon Height	(ft)	27.0	
Number of outer Columns		4	
Outer Column Height	(ft)	250.0	
Outer Column Side Length	(ft)	44 x 46	
Numbers of connecting pontoon		4	
Connecting pontoon Width	(ft)	46.0	
Connecting Pontoon Height	(ft)	27.0	
Distance between inner/outer columns (length of connecting pontoon)	(ft)	67.0	
Main deck dimension	(ft)	245' (EW)x217.5'(NS)	
Production deck dimension	(ft)	245' (EW)x217.5'(NS)	
Deck height (BOS to TOS)	(ft)	50.0	
Deck Post above Column	(ft)	6.0	
Deck Clearance (distance between TOS and MWL)	(ft)	75.0	

Objective

Building on recent development of dry tree systems, this project is aimed at delivering project-ready and cost competitive dry tree semi solutions for the GoM in a minimum of 8,000-ft (2,438-m) water depth with drilling and production capabilities for moderate to large payloads.

The objective has been to consider two promising hull forms with the associated riser tensioning systems that make use of conventional technologies to the greatest extent possible. Key technical challenges and/or new technologies, which require qualification before being field ready, are to be addressed with associated technology qualification plans developed.

The study also identified deployment opportunities associated with each solution with respect to field applications and considerations for overall safety, equipment limitations, fabrication, transportation, installation, and geographical locations.

Scope of work

RPSEA selected two awardees (KFD and HOE) for this study, each with its own unique hull form. Each awardee was tasked with providing a hull form and associated riser tensioning systems, while making use of conventional technologies to the extent possible. The work requires performing pre-front-end engineering and design (pre-FEED), equivalent engineering, and cost estimates. RPSEA also selected DNV GL to manage the project and to act as an independent third-party verifier for assessing the maturity of all safety and environmentally critical aspects of the concepts.

For the HOE concept, the following key issues were addressed:

- Vortex-induced-motion (platform behavior when subjected to high currents) – model test
- Qualification of riser tensioner equipment (confirmation by equipment suppliers that the forces, moments, and strokes are within the capacity of existing off-the-shelf tensioner equipment, and further design of the tensioner system including keel guide)
- Feasibility of quayside integration and transportation
- Evaluate the design basis for safe operation in the GoM, update the design configurations if needed, and perform engineering analysis accordingly

- Further engineering work and pursuit of an approval-in-principle by DNV GL
- For the Kvaerner concept, the following key issues were addressed:

- Further engineering with appropriate documentation of the conceptual design, including hull global design, airgap, stability, mooring, and riser configuration
- Evaluate the design basis for safe operation in GoM, update the design configurations if needed, and perform engineering analysis accordingly
- Further enhancement of structural design of riser interfaces with topsides and hull structures
- Qualification of the tensioning system:
 - Analyze structural integrity and stability of riser tensioning system
 - Perform a scaled model test of riser tensioner
 - Conduct a technical qualification of the riser tensioner system
- Perform a scaled model test of hull VIM
- Pursue an AiP evaluation by DNV GL.

Methodology

HOE and KFD further developed their dry tree semi concepts based on the scope defined in the proposal. The working project group (WPG) was established at the very beginning of the project. The WPG consists of subject matter specialists from the industry and DNV GL as well as the RPSEA project manager. Periodic WPG meetings have been arranged by DNV GL to review progress and seek input from subject matter specialists.

DNV GL used AiP as an approach to evaluate the overall concept feasibility. AiP is a typical process used for a class project to assess early conceptual feasibility. For this project, some design aspects that are beyond typical class scope but considered to be critical for dry tree semi concept (e.g. quayside integration) were also included in the evaluation. DNV GL also used its technology qualification (TQ) process for the riser tensioner qualification. Details of the AiP and TQ processes are described below.

Approval-in-principle

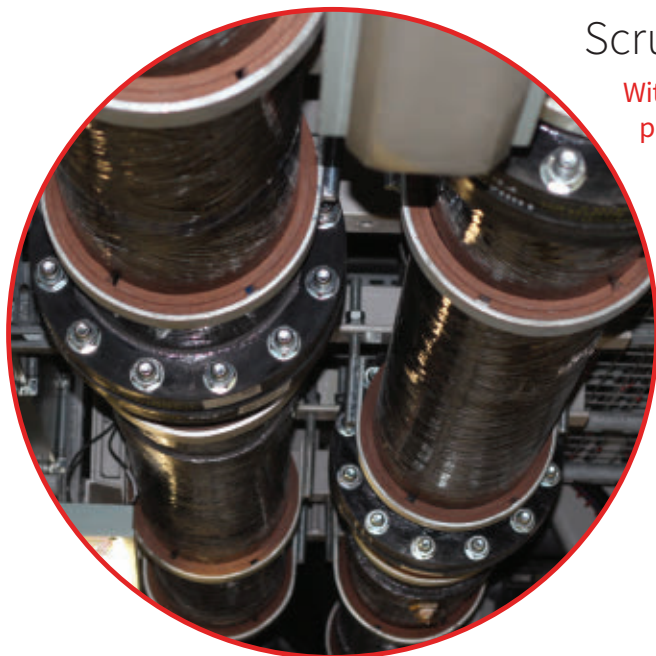
AiP is a structured process used by DNV GL to carry out an independent assessment of a concept within an agreed requirement framework. The aim of the AiP assessment is to confirm that the design is feasible and that there are no insurmountable obstacles (“showstoppers”) that would prevent the concept being realized. AiP is particularly useful to assess novel designs which will not be adequately addressed by existing recognized codes and standards.

The AiP approach is a risk-based approach, which is considered to be the most effective means of identifying and addressing hazards associated with a novel concept. Such hazards may arise from use of novel technology (or operation), from a novel application of existing technology and from an interface between novel and existing technology.

Identifying these areas is a key part of the AiP process, which is, initially, intuitive and, subsequently, part of a structured iterative process. Having identified hazards (or critical elements) to be further addressed, the AiP process will assess how the designer has addressed these concerns. Typically the designer will carry out risk and engineering studies to document the probability and consequence associated with the hazards and the effects of mitigation measures proposed.

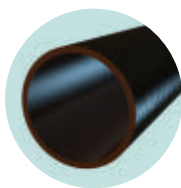
The AiP process will review documentation produced in the risk assessment, will confirm that all considered risks have been ade-

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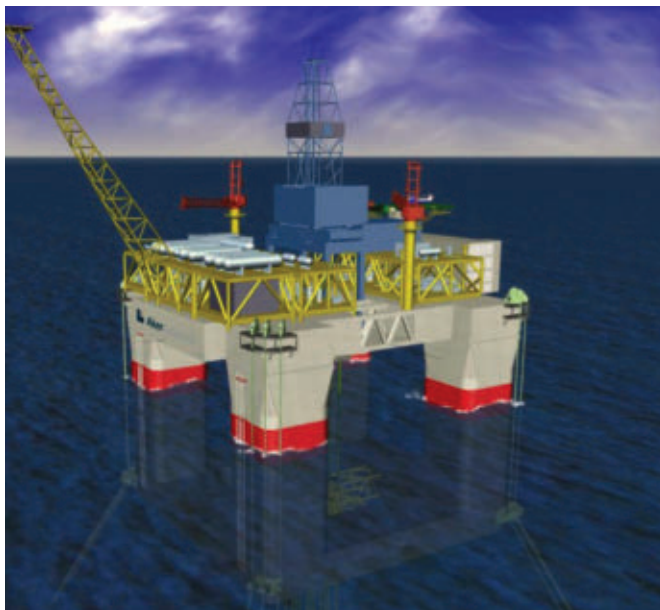
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Deepwater dry tree semisubmersible concept by Kvaerner Field Development (KFD). (Image courtesy KFD)

quately addressed, and that mitigation measures are considered appropriate. Compliance with relevant prescriptive requirements will also be considered. Depending on the design concept and its intended application, it may also be appropriate to consider any regulatory barriers which might impact the design. In addition, actions to be taken toward full classification will be listed.

As part of AiP process, conceptual HAZID workshop(s) should be held with subject specialists and the designers. Unlike a typical design HAZID, this conceptual HAZID is similar to a peer review workshop, which identifies potential challenges and risks of a concept. This would typically involve qualified personnel from DNV GL who would facilitate the workshop, together with a team of designer's specialists, industry subject matter specialists, and DNV GL specialists with experience in the design and intended operations.

This workshop would focus on critical design elements and systematically discuss the potential risks of the design concept. The intention is to identify potential showstoppers, identify design novelties (new technology or new application of existing technology), systematically assess "what if" scenarios of the identified elements to evaluate potential failure mechanism and consequences of failure, discuss mitigations/improvements, and thereafter determine the feasibility of the concept.

Technology qualification

The TQ process is defined as a "Qualification Procedure for New Technology." It is a procedure developed as part of the DEMO 2000 project funded by the Research Council of Norway. The Recommended Practice was developed to cover the need for a systematic approach to qualify new technology and ensure that the technology functions reliably within specified limits.

Design basis

DNV GL, in close collaboration with the WPG group, performed a comparison of the original design basis used by each designer. Some discrepancies and ambiguities were found, e.g. metocean data, acceptance criteria, etc. Some comments were raised on living quarter capacity, SCR configurations, etc. As an example, the definition in the original design basis did not seem to be practical for a safe operation in the GoM. Based on the above findings and comments received, up-

Key design data for Kvaerner Deepwater Dry Tree Semi.

DWDTS Hull and Mooring Configuration		
Hull Dimensions		
	Water depth (ft)	8,000
	Draft (ft)	145
	Main column c-c distance (ft)	236
	Main column width (ft)	72
	Column height (ft)	215
	Pontoon height (ft)	35
	Pontoon width (ft)	67
Load Balance		
	Topside weight (st)	34,600
	Hull weight (with fluid) (st)	46,404
	Riser loads (st)	17,740
	Mooring loads (st)	4,137
	Ballast water (st)	40,906
	Total platform displacement (st)	143,787
Mooring		
	Number of mooring lines	16
	Chain size/diameter (in)	6.0
	Polyester rope size/diameter (in)	10.75

dates were made to the design basis in order to develop the concepts for safer operations in the GoM. These updates resulted in additional design iterations and some extra engineering work.

HOE dry tree semi

The HOE PC Semi has two columns in each corner, which are connected by pontoons. The PC Semi configuration is different from a conventional deep draft semi in three aspects:

- Eight versus four columns
- Rectangular column versus square column
- Larger column slenderness ratio.

KFD dry tree semi

The DWDTS hull is built on a conventional deepwater semisubmersible concept with four corner columns and a ring pontoon. The hull size is 308 ft by 308 ft (93 m) and the total height is 215 ft (66 m). The proposed draft is 145 ft (44 m). Freeboard is 70 ft (21 m) to the bottom of the deck box and 105 ft to the top of the deck box from mean waterline. The mooring system of the DWDTS consists of 16 mooring lines clustered in four groups (4x4) with chain-polyester rope-chain segments for each line.

The topside facilities are modularized and supported by a deck box structure with overall dimensions 254 ft (77 m) long (EW), 354 ft wide (108 m), and 35 ft (11 m) deep. The process module is on the north side of the deck and the living quarter is on the south end. The well-bay is arranged in the center of the deck to accommodate production and drilling systems.

Concept evaluation

This project engaged subject matter specialists to evaluate the concepts starting from establishing the design basis, to model tests and conceptual HAZID workshops. A WPG was established in the very beginning of the project to engage subject matter specialists from Chevron, ConocoPhillips, Statoil, Total, Marathon Oil, and RPSEA. WPG meetings were held on regular basis (every 1-2 months) until the final workshop was conducted. The project participants (DNV GL, HOE, and KFD) also published several papers and held presentations at OTC Houston, OTC Brazil, and RPSEA conferences.

The objective of such industry participation and publication was to seek advice and feedback from the subject matter specialists and end users to ensure that concept development is in line with industry practice, and meets the requirements of a safe operation in the GoM. ●

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Advances in rotary steerable systems improve efficiency

Dick Ghiselin
Contributing Editor

Service providers describe technology improvements that decrease drilling costs

The first patents for so-called steerable systems were issued in the late 1800s, and applied primarily in water wells. A full century passed before modern rotary steerable systems (RSS) made their oilfield debut, reportedly on BP's Wytch Farm extended-reach play. A major advantage of rotary steerable systems is improved drilling efficiency. The steerable feature adds value by enabling the wellbore trajectory to be adjusted according to geological information retrieved in real-time from the downhole tools. The benefit is having the ability to steer into so-called reservoir "sweet spots." Today, with depressed oil and gas prices, operators are primarily concerned with cost reduction. *Offshore* asked four RSS providers for an update on their latest efforts to improve drilling efficiency and add value. Their responses follow in the order received.

Halliburton

The Geo-Pilot Dirigo 11K series RSS features a larger drive shaft and 55,000 ft-lb torque rating. According to the company, this amounts to industry-leading maximum load carrying capability. It was developed to support large borehole size drilling through hard formations, specifically salt, enabling faster drilling of difficult sections. The addition of a stabilizer to the bottom end of the tool moves the fulcrum point to the lower housing section. This geometry improves steerability, reduces vibration, and decreases stress on the RSS enabling a higher rate of penetration. The Geo-Pilot Dirigo 11K system has been successfully deployed offshore in the Gulf of Mexico and in Brazil.

Part of the Sperry Drilling Services Pilot fleet of automated drilling systems, the new equipment is particularly effective in transition zone drilling. The company says the system offers consistently higher build rates in large borehole sizes, primarily due to its point-the-bit feature and a strategically-placed stabilizer just above the drill bit. Especially in shallow reservoirs, consistent dog-legs are required to drill successfully the shallow soft formations. Build rates of 10°/100 ft are achievable in larger boreholes and 15°/100



A key feature of the Geo-Pilot Dirigo 11K system is the near-bit stabilizer that acts equally as a powerful fulcrum for trajectory changes, and a precise stabilizer for the bit and Gamma Ray sensor. (Image courtesy Halliburton)

ft in smaller diameters. This allows drillers to kick-off their laterals deeper and still land in the heart of the reservoir. All Sperry's logging-while-drilling (LWD) systems are compatible with the Geo-Pilot Dirigo 11K system. Record-setting performance was recorded in China's Tarim basin where three days of rig time were saved while steering through thin reservoir sections. A coverage rate of 98% was achieved. Geosteering was achieved through the use of an at-the-bit gamma ray sited just 1 m (3 ft) above the bit.

Baker Hughes

New RSS developments have been driven by the rise of shale drilling where there was a need to stay within lease lines, yet still drill

the longest possible laterals. Therefore, a new RSS was developed, the Baker Hughes AutoTrak Curve RSS system. According to the company, many operators have chosen to use AutoTrak Curve on all their wells due to the improved economics and the boosting of the net present value of their wells.

A new release, the AutoTrak eXact system is fully compatible with all LWD high build-rate equipment. Many operators in conventional applications have accepted the idea of higher build-rate drilling up to 12°/100 ft (30 m). For operators in conventional plays, this provides the ability to reduce drilling footage, avoiding directional work in problematic formations, and ultimately avoiding risk, thus saving time. The use of RSS in these wells has also meant the vertical, curve, and lateral sections can be drilled in one run. Additionally, the high build-rate capability means changes in geological structure can be reacted-to faster, and there is added confidence in achieving build rates where conventional systems may have had problems in the past.

The AutoTrak eXact system was introduced in September 2014 and since then has been used on many wells in the Middle East



To deliver higher build-rates, the AutoTrak eXact RSS was redesigned to incorporate larger pads and a three-point geometry that brought the pads closer to the bit. (Photo courtesy Baker Hughes)



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and North America. It was developed primarily for the conventional market, where there is a need for high build-rates simultaneously with acquiring LWD data. Extensive finite element analysis was carried out on a multitude of bottomhole assemblies (BHA) resulting in recommendations of standard BHAs that were optimized for the higher build rates and DLS.

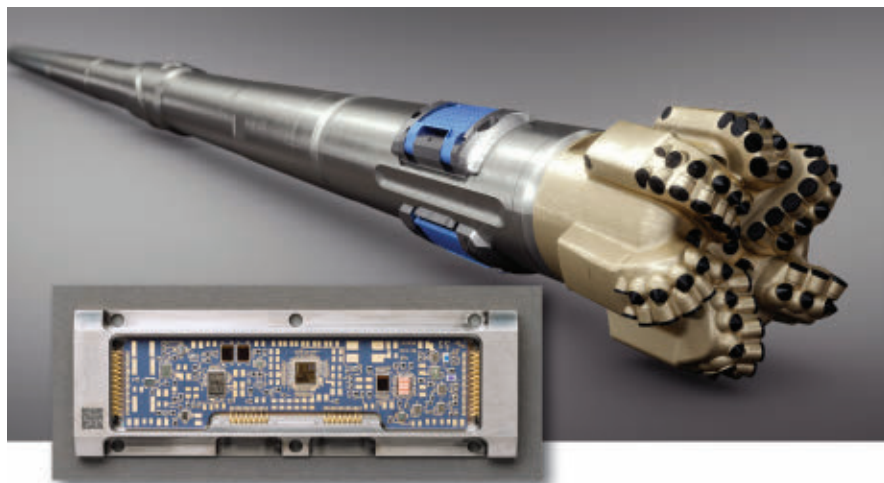
The AutoTrak eXact system has shown significant value in its ability to deliver oriented kick-off from vertical while achieving high build rates and drilling longer laterals with high accuracy. It has also been used in formations that are extremely soft and unconsolidated where the use of RSS has been avoided in the past, and it has exceeded expectations with respect to rate of penetration and steering performance.

Weatherford

In the Middle East Tinat field, the use of the Revolution RSS saved the company's client \$350,000 and a week of drill time by eliminating the need for drill pipe-conveyed wireline tough-logging-condition (TLC) operations.

Tasked with drilling a 5-in. horizontal section out of a 7-in. cement float and shoe to reach total depth in one run, Weatherford engineers recommended the penta-combo 4¾-in. LWD tool string featuring the Spectral-Wave azimuthal gamma ray and CrossWave azimuthal sonic tools. These services were used for data on formation porosity and for advanced elemental and petrophysical analysis of the reservoir. First, a full torque-and-drag hydraulic analysis was performed in order to design a BHA to eliminate TLC and optimize the rate of penetration (ROP). Then the LWD string was designed to acquire all the reservoir and geosteering data requested by the operator.

The entire 1,456-ft (444-m) lateral section was drilled to a 17,059-ft (5,200-m) TD in a single run, while averaging 41 ft-12 m/hr ROP at approximately 250°F (121.1°C). The



The PowerDrive ICE RSS is a push-the-bit system presently available in 6.75-in. diameter. The TeleScope ICE system is available in 6.75-in. and 4.75-in. sizes. (Courtesy Schlumberger)

DownLink Commander was used for rapid, two-way communication with the BHA and the Revolution RSS for higher ROP and a smoother borehole.

Schlumberger

To tackle the growing number of high-pressure/high-temperature (HP/HT) wells, Schlumberger has developed an entire new tool system. Its name is ICE, ultra-high-temperature drilling services. ICE stands for Integrated Ceramic Electronics. This name is assigned to the new PowerDrive ICE RSS and the Telescope ICE high-speed telemetry service, but there is nothing cool about its record-breaking temperature capability. The system's operating temperature has been certified to 392°F (200°C) at pressures of 30,000 psi (207 bar) for 2,000 hours without failure.

Tested in the GoM and the Gulf of Thailand, where some of the hottest wells on the planet exist, the tool achieved its chief design criteria – uninterrupted drilling processes and provision of all required services. Testing included thermal shock cycling

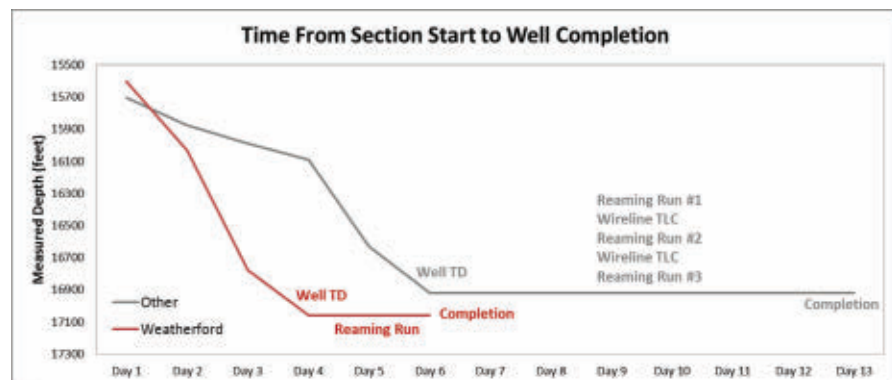
over a range of -72°F (-40°C) through 392°F (200°C). ICE electronic components use reliable ultra-high temperature multichip modules which include a ceramic substrate. The PowerDrive ICE dynamic elastomeric seals have been completely replaced by metal-to-metal ones.

The TeleScope ICE provides azimuthal gamma ray for steering, direction and inclination sensors, four-axis vibration, pressure, and temperature with two-way mud-pulse telemetry. Both the MWD and RSS tools are turbine powered and contain no batteries. The RSS tool operates up to 350 rpm for maximum ROP. The temperature rating applies to the system itself, not the formation temperature; thus it can successfully negotiate formations hotter than its rated temperature.

On its debut in Mexico, the PowerDrive ICE RSS saved nine days of rig time, conservatively valued at \$1.35 million. This achievement was enhanced by a 16% ROP improvement drilling the well's 8½-in. tangent section over ROPs experienced in off-set wells. The borehole trajectory steered from 77° to 57° azimuth to reach the 3D target set by PEMEX. Bottomhole conditions exceeded 329°F (165°C) and pressures greater than 15,000 psi (1,034 bar).

Originally, the operator experienced issues maintaining trajectory with a packed BHA. The pipe was tripped and the PowerDrive ICE RSS was deployed to recover the tangent section and withstand the high formation temperatures.

In Thailand, PTTEP drills more than 50 gas wells per year with BHT's greater than 200°C. Using the TeleScope ICE service, the operator was able to drill and steer successfully to target depth with measured formation temperatures of 399°F (204°C). A 13% rig time saving was achieved. ●



The lateral section was drilled more efficiently in one run using the Revolution RSS than previous runs that depended on wireline TLC techniques for formation evaluation. (Courtesy Weatherford)



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2015 Rotary steerable drilling systems directory

Product trade name	Point-the-bit or Push-the-bit?	Length (ft)	O. D. & I. D. (inches)	Hole size (inches)	Max DLS capability (°/100')	Automated closed loop deviation control (yes/no) (+/-degrees)	Build rate increment	Is deviation force continuous?	Max temp (°C /°F)	Max internal pressure (psi)	Other special pressure limitations	Require configuration based on anticipated flow rate?
Baker Hughes http://www.bakerhughes.com												
6.75" AutoTrak Curve (High Buildup Rate RSS)	Hybrid of point and push	38 (fully inclusive of steering system & MWD) Steering head length = 9.3	OD: 6.75 ID: N/A	8.375 - 9.875	15	Yes Precise to within 0.2°	Build Force programmable from surface via downlink. Target inclination in 0.125° increments	Yes	150/302	20,000	None	Steering system: No MWD system: No
9.5" AutoTrak G3.0 RCLS	Hybrid of point and push	58 (fully inclusive of steering system & MWD/LWD) Steering head length = 8.2	OD: 9.5 ID: N/A	12.00 - 28.00	6.5	Yes Precise to within 0.1°	Build Force programmable from surface via downlink. Target inclination in 0.125° increments	Yes	150/302 (175/347 on request)	20,000 (25,000 & 30,000 on request)	None	Steering system: No MWD system: Yes
8.25" AutoTrak G3.0 RCLS	Hybrid of point and push	57 (fully inclusive of steering system & MWD/LWD) Steering head length = 7.2	OD: 8.25 ID: N/A	10.625	6.5	Yes Precise to within 0.1°	Build Force programmable from surface via downlink. Target inclination in 0.125° increments	Yes	150/302 (175/347 on request)	20,000 (25,000 & 30,000 on request)	None	Steering system: No MWD system: Yes
6.75" AutoTrak G3.0 RCLS	Hybrid of point and push	50 (fully inclusive of steering system & MWD/LWD) Steering head length = 7.2	OD: 6.75 ID: N/A	8.375 - 10.625	6.5	Yes Precise to within 0.1°	Build Force programmable from surface via downlink. Target inclination in 0.125° increments	Yes	150/302 (175/347 on request)	20,000 (25,000 & 30,000 on request)	None	Steering system: No MWD system: Yes
4.75" AutoTrak G3.0 RCLS	Hybrid of point and push	48 (fully inclusive of steering system & MWD/LWD) Steering head length = 9.97	OD: 4.75 ID: N/A	5.75 - 6.75	10	Yes Precise to within 0.1°	Build Force programmable from surface via downlink. Target inclination in 0.125° increments	Yes	150/302	20,000 (25,000 on request)	None	Yes
4.75" AutoTrak with ZoneTrak G RCLS	Hybrid of point and push	50 (fully inclusive of steering system, NBG & MWD/LWD) Steering head length = 12.3	OD: 4.75 ID: N/A	5.75 - 6.75	10	Yes Precise to within 0.1°	Build Force programmable from surface via downlink. Target inclination in 0.125° increments	Yes	125/257	20,000 (25,000 & 30,000 on request)	None	Yes
9.5" AutoTrak X-treme (Adds Integrated pre-contoured drilling motor)	Hybrid of point and push	88 (fully inclusive of steering system, motor power section & MWD/LWD) Steering head length = 8.2	OD: 9.5 ID: N/A	12.00 - 28	6.5	Yes Precise to within 0.1°	Build Force programmable from surface via downlink. Target inclination in 0.125° increments	Yes	150/302 (175/347 on request)	20,000 (25,000 & 30,000 on request)	None	Steering system: No MWD system: Yes
6.75" AutoTrak X-treme (Adds Integrated pre-contoured drilling motor)	Hybrid of point and push	76 (fully inclusive of steering system, motor power section & MWD/LWD) Steering head length = 7.2	OD: 6.75 ID: N/A	8.375 - 10.625	6.5	Yes Precise to within 0.1°	Build Force programmable from surface via downlink. Target inclination in 0.125° increments	Yes	150/302 (175/347 on request)	20,000 (25,000 & 30,000 on request)	None	Steering system: No MWD system: Yes
4.75" AutoTrak X-treme (Adds Integrated pre-contoured drilling motor)	Hybrid of point and push	75 (fully inclusive of steering system, motor power section & MWD/LWD) Steering head length = 10.5	OD: 4.75 ID: N/A	5.875 - 6.75	10	Yes Precise to within 0.1°	Build Force programmable from surface via downlink. Target inclination in 0.125° increments	Yes	150/302	20,000 (25,000 on request)	None	Yes
4.75" AutoTrak X-treme with ZoneTrak G (Adds Integrated pre-contoured drilling motor)	Hybrid of point and push	77 (fully inclusive of steering system, motor power section, NBG & MWD/LWD) Steering head length = 12.3	OD: 4.75 ID: N/A	5.875 - 6.75	10	Yes Precise to within 0.1°	Build Force programmable from surface via downlink. Target inclination in 0.125° increments	Yes	125/257	20,000 (25,000 on request)	None	Yes
9.5" AutoTrak eXpress RCLS (Base level RSS service)	Hybrid of point and push	64.6 (fully inclusive of steering system & MWD) Steering head length = 8.2	OD: 9.5 ID: N/A	12.00 - 28.00	6.5	Yes Precise to within 0.1°	Programmable from surface via downlink from 0-6.5° /100 ft	Yes	150/302	20,000	None	Steering system: No MWD system: Yes
6.75" AutoTrak eXpress RCLS (Base level RSS service)	Hybrid of point and push	58.2 (fully inclusive of steering system & MWD) Steering head length = 7.2	OD: 6.75 ID: N/A	8.375 - 10.625	8	Yes Precise to within 0.1°	Programmable from surface via downlink from 0-8° /100 ft	Yes	150/302	20,000	None	Steering system: No MWD system: Yes

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Sensor distance (ft) Inc/Azm/GR/Res	Control from surface (Downlink)? (Y / N)	If yes, tool control method	Req'd to communicate change in target (minutes)	Minimum kickoff inclination (degrees)	Max RPM / WOB	Min flow rate (gpm)	Max flow rate (gpm)	LCM limits	Power source	Bit requirements	Integrated LWD?
5.9 / 21.6 / 11.5 / NA	Y	Negative pulse from surface skid unit	While drilling ahead	0	250 RPM 56 klbf	300	750	50 lb/bbl medium nutplug, Cedar Fiber	Turbine generator	Application specific	NO
3.9 / 33.1 / 24.3 / 25.6	Y	Negative pulse from surface skid unit	While drilling ahead	0	300 RPM 100 klbf	300	1,600	Steering system: None MWD system: 40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	Yes
3.1 / 32.4 / 20.3 / 25.6	Y	Negative pulse from surface skid unit	While drilling ahead	0	400 RPM 57 klbf	300	1,290	Steering system: None MWD system: 40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	Yes
3.1 / 27.5 / 17.7 / 21.6	Y	Negative pulse from surface skid unit	While drilling ahead	0	400 RPM 57 klbf	200	900	Steering system: None MWD system: 40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	Yes
4.3 / 26.2 / 13.0 / 20.2	Y	Negative pulse from surface skid unit	While drilling ahead	0	400 RPM 22.5 klbf	125	350	40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	Yes
3.9 / 28 / 5.7 / 22	Y	Negative pulse from surface skid unit	While drilling ahead	0	400 RPM 22.5 klbf	125	350	40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	Yes
Inc: 3.9 Others BHA dependent	Y	Negative pulse from surface skid unit	While drilling ahead	0	300 RPM 60 klbf	530	1,600	Steering system: None MWD system: 40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	Yes
Inc: 3.1 Others BHA dependent	Y	Negative pulse from surface skid unit	While drilling ahead	0	400 RPM 36 klbf	265	660	Steering system: None MWD system: 40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	Yes
Inc: 4.3 Others BHA dependent	Y	Negative pulse from surface skid unit	While drilling ahead	0	400 RPM 14.6 klbf	105	315	40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	Yes
Inc: 3.9 NBG: 5.7 Others BHA dependent	Y	Negative pulse from surface skid unit	While drilling ahead	0	400 RPM 14.6 klbf	105	315	40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	Yes
3.9 / 40.8 / 37.5 / NA	Y	Flow rate change	While drilling ahead	0	300 RPM 100 klbf	300	1,600	Steering system: None MWD system: 40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	NO
3.1 / 34.7 / 31.5 / NA	Y	Flow rate change	While drilling ahead	0	400 RPM 55 klbf	200	900	Steering system: None MWD system: 40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	NO



Power Sections

Sizes: 1 11/16 in - 11 1/2 in

Dyna-Drill

2015 Rotary steerable drilling systems directory

Product trade name	Point-the-bit or Push-the-bit?	Length (ft)	O. D. & I. D. (inches)	Hole size (inches)	Max DLS capability (°/100')	Automated closed loop deviation control (yes/no) (+/-degrees)	Build rate increment	Is deviation force continuous?	Max temp (°C /°F)	Max internal pressure (psi)	Other special pressure limitations	Require configuration based on anticipated flow rate?
4.75" AutoTrak eXpress RCLS (Base level RSS service)	Hybrid of point and push	56.8 BHA inclusive of steering system & MWD Steering head length = 9.97	OD: 4.75 ID: N/A	5.75 - 6.75	10	Yes Precise to within 0.1°	Programmable from surface via downlink from 0-10° /100 ft	Yes	150/ 302	20,000	None	Yes
4.75" AutoTrak eXpress with ZoneTrak G RCLS (Base level RSS service)	Hybrid of point and push	58.8 BHA inclusive of steering system & MWD Steering head length = 12.3	OD: 4.75 ID: N/A	5.75 - 6.75	10	Yes Precise to within 0.1°	Programmable from surface via downlink from 0-10° /100 ft	Yes	125/ 257	20,000	None	Yes
9.5" AutoTrak V RCLS for vertical drilling	Hybrid of point and push	24 fully inclusive. Steering head = 8.2	OD: 9.5 ID: N/A	12.00 - 28.00	Vertical Drilling	Yes Precise to within 0.1°	Vertical Drilling	Yes	150/ 302	20,000 (25,000 & 30,000 on request)	None	No
6.75" AutoTrak V RCLS for vertical drilling	Hybrid of point and push	21 fully inclusive. Steering head = 7.2	OD: 6.75 ID: N/A	8.375 - 10.625	Vertical Drilling	Yes Precise to within 0.1°	Vertical Drilling	Yes	150/ 302	20,000 (25,000 & 30,000 on request)	None	No
4.75" AutoTrak V RCLS for vertical drilling	Hybrid of point and push	24 fully inclusive. Steering head = 10.5	OD: 4.75 ID: N/A	5.75 - 6.75	Vertical Drilling	Yes Precise to within 0.1°	Vertical Drilling	Yes	150/ 302	20,000 (25,000 on request)	None	Yes
4.75" AutoTrak V with ZoneTrak G RCLS for vertical drilling	Hybrid of point and push	26 fully inclusive. Steering head = 12.3	OD: 4.75 ID: N/A	5.75 - 6.75	Vertical Drilling	Yes Precise to within 0.1°	Vertical Drilling	Yes	125/ 257	20,000 (25,000 on request)	None	Yes
6.75" AutoTrak eXact (High Buildup Rate RSS)	Hybrid of point and push	38 (fully inclusive of steering system & MWD) Steering head length = 9.3	OD: 6.75 ID: N/A	8.375 - 9.875	15	Yes Precise to within 0.2°	Build Force programmable from surface via downlink. Target inclination in 0.125° increments	Yes	150/ 302	20,000	None	Steering system: No MWD system: No
Halliburton Sperry Drilling Jim Tilley Product Manager - Rotary Steerable Systems (Jim.Tilley@halliburton.com) www.halliburton.com												
Geo-Pilot System 5200 Series	Point	16.2 + 11.5 flex collar	OD: 5.25 ID: 1.125	5.875 - 6.75	10	Yes within 0.1° SOLAR Version	0-100% in 1° increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	150/ 302	20,000	None	No
Geo-Pilot XL System 5200 Series	Point	16.2 + 11.5 flex collar	OD: 5.25 ID: 1.125	5.875 - 6.75	10	Yes within 0.1° Solar Version	0-100% in 1° increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	150/ 302	20,000	None	No
Geo-Pilot Dirigo System 5200 Series	Point	16.2 + 11.5 flex collar	OD: 5.25 ID: 1.125	5.875 - 6.75	15	Yes within 0.1° Solar Version	0-100% in 1° increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	150/ 302	20,000	None	No
Geo-Pilot XL System 5200 Series SOLAR XHP	Point	16.2	OD: 5.25 ID: 1.125	5.875 - 6.75	10	Yes within 0.1°	0-100% in 1° increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	175 / 347	30,000	None	No
Geo-Pilot System 7600 Series	Point	20	OD: 7.625 ID: 1.625	8.375 - 10.625	5	Yes within 0.1°	0-100% in 1° increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	150/ 302	18,000	None	No
Geo-Pilot XL System 7600 Series	Point	20	OD: 7.625 ID: 1.625	8.375 - 10.625	5	Yes within 0.1°	0-100% in 1° increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	150/ 302	18,000	None	No
Geo-Pilot Dirigo System 7600 Series	Point	20	OD: 7.625 ID: 1.625	8.375 - 10.625	10	Yes within 0.1°	0-100% in 1° increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	150/ 302	18,000	None	No
Geo-Pilot XL System Vertical Mode 7600 Series	Point	20	OD: 7.625 ID: 1.625	8.375 - 10.625	N/A	0.25° Verticality	0-100% in 1° increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	150/ 302	18,000	None	No
Geo-Pilot XL System 7600 Series SOLAR	Point	20	OD: 7.625 ID: 1.625	8.375 - 10.625	5	Yes within 0.1°	0-100% in 1° increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	175 / 347	25,000	None	No
Geo-Pilot XL System 7600 Series XHP	Point	20	OD: 7.625 ID: 1.625	8.375 - 10.625	5	Yes within 0.1°	0-100% in 1° increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	150/ 302	30,000	None	No
Geo-Pilot XL System 7600 Series SOLAR XHP	Point	20	OD: 7.625 ID: 1.625	8.375 - 10.625	5	Yes within 0.1°	0-100% in 1° increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	175/ 347	30,000	None	No

Sensor distance (ft) Inc/Azm/GR/Res	Control from surface (Downlink)? (Y / N)	If yes, tool control method	Req'd to communicate change in target (minutes)	Minimum kickoff inclination (degrees)	Max RPM / WOB	Min flow rate (gpm)	Max flow rate (gpm)	LCM limits	Power source	Bit requirements	Integrated LWD?
4.3 / 32.9 / 29.6 / NA	Y	Flow rate change	While drilling ahead	0	400 RPM 22.5 klbf	125	350	40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	NO
3.9 / 32.9 / 5.7 / NA	Y	Flow rate change	While drilling ahead	0	400 RPM 22.5 klbf	125	350	40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	NO
3.9 / NA / NA / NA	Y	Flow rate change	While drilling ahead	0	250 RPM 100 klbf	300	1,600	Steering system: None MWD system: 40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	NO
3.1 / NA / NA / NA	Y	Flow rate change	While drilling ahead	0	250 RPM 55 klbf	200	900	Steering system: None MWD system: 40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	NO
3.9 / NA / NA / NA	Y	Flow rate change	While drilling ahead	0	250 RPM 22.5 klbf	125	350	Steering system: None MWD system: 40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	NO
3.9 / NA / 5.7 / NA	Y	Flow rate change	While drilling ahead	0	250 RPM 22.5 klbf	125	350	Steering system: None MWD system: 40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	NO
5.9 / 21.6 / 11.5 / NA	Y	Negative pulse from surface skid unit	While drilling ahead	0	250 RPM 56 klbf	300	750	50 lb/bbl medium nutplug, Cedar Fiber	Turbine generator	Application specific	YES
10/32/32/42	Y	Negative pulse from surface skid unit	0	0	250 RPM 25klb	Recommend 500 psi differential across MWD for telemetry	5,000 lbs/min (e.g., 333 gpm @ 15.0 ppg)	None	Lithium batteries	Application specific	Yes
10/32/32/42	Y	Negative pulse from surface skid unit	0	0	250 RPM 25klb	Recommend 500 psi differential across MWD for telemetry	5,000 lbs/min (e.g., 333 gpm @ 15.0 ppg)	None	Lithium batteries	Application specific	Yes
10/32/32/42	Y	Negative pulse from surface skid unit	0	0	250 RPM 25klb	Recommend 500 psi differential across MWD for telemetry	5,000 lbs/min (e.g., 333 gpm @ 15.0 ppg)	None	Lithium batteries	Application specific	Yes
10/20/22/32	Y	Negative pulse from surface skid unit	0	0	250 RPM 25klb	Recommend 500 psi differential across MWD for telemetry	5,000 lbs/min (e.g., 333 gpm @ 15.0 ppg)	None	MWD Generator	Application specific	Yes
3/23/3/40	Y	Negative pulse from surface skid unit	0	0	250 RPM 55klb	Recommend 500 psi differential across MWD for telemetry	10,000 lbs/min (e.g., 1,000 gpm @10 ppg)	None	Lithium batteries	Application specific	Yes
3/23/3/40	Y	Negative pulse from surface skid unit	0	0	250 RPM 55klb	Recommend 500 psi differential across MWD for telemetry	10,000 lbs/min (e.g., 1,000 gpm @10 ppg)	None	Lithium batteries	Application specific	Yes
3/23/3/40	Y	Negative pulse from surface skid unit	0	0	250 RPM 55klb	Recommend 500 psi differential across MWD for telemetry	10,000 lbs/min (e.g., 1,000 gpm @10 ppg)	None	Lithium batteries	Application specific	Yes
3/23/3/40	Y	Negative pulse from surface skid unit	0	0	250 RPM 55klb	Recommend 500 psi differential across MWD for telemetry	10,000 lbs/min (e.g., 1,000 gpm @10 ppg)	None	Lithium batteries	Application specific	Yes
3/23/3/40	Y	Negative pulse from surface skid unit	0	0	250 RPM 55klb	Recommend 500 psi differential across MWD for telemetry	10,000 lbs/min (e.g., 1,000 gpm @10 ppg)	None	Lithium batteries	Application specific	Yes
3/23/3/40	Y	Negative pulse from surface skid unit	0	0	250 RPM 55klb	Recommend 500 psi differential across MWD for telemetry	10,000 lbs/min (e.g., 1,000 gpm @10 ppg)	None	Lithium batteries	Application specific	Yes
3/23/3/40	Y	Negative pulse from surface skid unit	0	0	250 RPM 55klb	Recommend 500 psi differential across MWD for telemetry	10,000 lbs/min (e.g., 1,000 gpm @10 ppg)	None	Lithium batteries	Application specific	Yes

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Product trade name	Point-the-bit or Push-the-bit?	Length (ft)	O. D. & I. D. (inches)	Hole size (inches)	Max DLS capability (°/100')	Automated closed loop deviation control (yes/no) (+/-degrees)	Build rate increment	Is deviation force continuous?	Max temp (°C /°F)	Max internal pressure (psi)	Other special pressure limitations	Require configuration based on anticipated flow rate?
Geo-Pilot System 9600 Series	Point	22	OD: 9.625 ID: 2.375	12.0 - 26	6	Yes within 0.1°	0-100% in 1% increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	150/ 302	20,000	None	No
Geo-Pilot XL System 9600 Series	Point	22	OD: 9.625 ID: 2.375	12.0 - 26	6	Yes within 0.1°	0-100% in 1% increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	150/ 302	20,000	None	No
Geo-Pilot Dirigo System 9600 Series	Point	22	OD: 9.625 ID: 2.375	12.0 - 17 1/2"	10	Yes within 0.1°	0-100% in 1% increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	150/ 302	20,000	None	No
Geo-Pilot XL System Vertical Mode 9600 Series	Point	22	OD: 9.625 ID: 2.375	12.0 - 26	N/A	0.25° Verticality	0-100% in 1% increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	150/ 302	20,000	None	No
Geo-Pilot XL System 9600 Series SOLAR	Point	22	OD: 9.625 ID: 2.375	12.0 - 26	6	Yes within 0.1°	0-100% in 1% increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	175/ 347	25,000	None	No
Geo-Pilot XL System 9600 Series XHP	Point	22	OD: 9.625 ID: 2.375	12.0 - 26	6	Yes within 0.1°	0-100% in 1% increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	150/ 302	30,000	None	No
Geo-Pilot XL System 9600 Series SOLAR XHP	Point	22	OD: 9.625 ID: 2.375	12.0 - 26	6	Yes within 0.1°	0-100% in 1% increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	175/ 347	30,000	None	No
Geo-Pilot 11K High Torque RSS	Point	22	OD: 10.875 ID: 1.75	14.5 - 26	6	Yes within 0.1°	0-100% in 1% increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	150/ 302	20,000	None	No
Geo-Pilot GXT System 5200 XL Series (Integrated GeoForce even-wall power section)	Point	16.2 + 11.5 flex collar + 27.4 (power section)	OD: 5.25 ID: 1.125	5.875 - 6.75	10	Yes within 0.1°	0-100% in 1% increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	150 / 302	20,000	None	No
Geo-Pilot GXT System 5200 XL Series SOLAR (Integrated GeoForce even-wall power section)	Point	16.2 + 27.4 (power section)	OD: 5.25 ID: 1.125	5.875 - 6.75	10	Yes within 0.1°	0-100% in 1% increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	175 / 347	20,000	None	No
Geo-Pilot GXT System 7600 XL Series (Integrated GeoForce even-wall power section)	Point	20 + 27.4 (power section)	OD: 7.625 ID: 1.625	8.375 - 10.625	5	Yes within 0.1°	0-100% in 1% increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	150/ 302	18,000	None	No
Geo-Pilot GXT System 7600 XL Series SOLAR (Integrated GeoForce even-wall power section)	Point	20 + 27.4 (power section)	OD: 7.625 ID: 1.625	8.375 - 10.625	5	Yes within 0.1°	0-100% in 1% increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	175/ 347	20,000	None	No
Geo-Pilot GXT System 9600 XL Series (Integrated GeoForce even-wall power section)	Point	22 + 29.7 (power section)	OD: 9.625 ID: 2.375	12.0 - 26	6	Yes within 0.1°	0-100% in 1% increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	150/ 302	20,000	None	No
Geo-Pilot GXT System 9600 XL Series SOLAR (Integrated GeoForce even-wall power section)	Point	22 + 29.7 (power section)	OD: 9.625 ID: 2.375	12.0 - 26	6	Yes within 0.1°	0-100% in 1% increments, and 3° TF increments	Yes >12,000 Steering vectors continuously available	175/ 347	20,000	None	No
National Oilwell Varco												
Lateral Drilling Tool (LDT)	Push-the-bit	27 ft	4.75" OD 1.125" ID	5-5/8" - 6 3/4"	3 deg./100'	No		Yes	400 deg. F	N/A	N/A	No
Schlumberger +1-281-285-8500												
PowerDrive Xceed 675	Point	25	OD: 6.75 ID: N/A	8.375 - 9.875	8	Yes +/- 0.1°	1% and 1° TF resolution	Adjustable	150/ 302	20,000	None	Yes
PowerDrive Xceed 900	Point	28	OD: 9.00 ID: N/A	12.25 - 17.5	6.5	Yes +/- 0.1°	1% and 1° TF resolution	Adjustable	150/ 302	20,000	None	Yes
PowerDrive X6 1100	Push	15.22	OD: 9.5 ID: N/A	15.5 - 28	4	Yes +/- 0.1°	1% and 1° TF resolution	Adjustable	150/ 302	25,000	Adjustable within a 200 psi pressure range at the bit	Yes
PowerDrive X6 900	Push	14.07	OD: 9.0 ID: N/A and OD: 9.625 (EL)	12 - 14.75 and 15.5 - 18.5 (EL)	5	Yes +/- 0.1°	1% and 1° TF resolution	Adjustable	150/ 302	25000 (35,000 Optional)	Adjustable within a 200 psi pressure range at the bit	Yes

Sensor distance (ft) Inc/Azm/GR/Res	Control from surface (Downlink)? (Y / N)	If yes, tool control method	Req'd to communicate change in target (minutes)	Minimum kickoff inclination (degrees)	Max RPM / WOB	Min flow rate (gpm)	Max flow rate (gpm)	LCM limits	Power source	Bit requirements	Integrated LWD?
3/23/3/40	Y	Negative pulse from surface skid unit	0	0	250 RPM 100klb	Recommend 500 psi differential across MWD for telemetry	20,000 lbs/min (e.g., 2,000 gpm @10 ppg)	None	Lithium batteries	Application specific	Yes
3/23/3/40	Y	Negative pulse from surface skid unit	0	0	250 RPM 100klb	Recommend 500 psi differential across MWD for telemetry	20,000 lbs/min (e.g., 2,000 gpm @10 ppg)	None	Lithium batteries	Application specific	Yes
3/23/3/40	Y	Negative pulse from surface skid unit	0	0	250 RPM 100klb	Recommend 500 psi differential across MWD for telemetry	20,000 lbs/min (e.g., 2,000 gpm @10 ppg)	None	Lithium batteries	Application specific	Yes
3/23/3/40	Y	Negative pulse from surface skid unit	0	0	250 RPM 100klb	Recommend 500 psi differential across MWD for telemetry	20,000 lbs/min (e.g., 2,000 gpm @10 ppg)	None	Lithium batteries	Application specific	Yes
3/23/3/40	Y	Negative pulse from surface skid unit	0	0	250 RPM 100klb	Recommend 500 psi differential across MWD for telemetry	20,000 lbs/min (e.g., 2,000 gpm @10 ppg)	None	Lithium batteries	Application specific	Yes
3/23/3/40	Y	Negative pulse from surface skid unit	0	0	250 RPM 100klb	Recommend 500 psi differential across MWD for telemetry	20,000 lbs/min (e.g., 2,000 gpm @10 ppg)	None	Lithium batteries	Application specific	Yes
3/23/3/40	Y	Negative pulse from surface skid unit	0	0	250 RPM 100klb	Recommend 500 psi differential across MWD for telemetry	20,000 lbs/min (e.g., 2,000 gpm @10 ppg)	None	Lithium batteries	Application specific	Yes
3/23/3/40	Y	Negative pulse from surface skid unit	0	0	250 RPM 100klb	Recommend 500 psi differential across MWD for telemetry	20,000 lbs/min (e.g., 2,000 gpm @10 ppg)	None	Lithium batteries	Application specific	Yes
10/32/32/70	Y	Negative pulse from surface skid unit	0	0	250 RPM 25klb	Recommend 500 psi differential across MWD for telemetry	5,000 lbs/min (e.g., 333 gpm @ 15.0 ppg)	None	Lithium batteries	Application specific	Yes
10/20/22/70	Y	Negative pulse from surface skid unit	0	0	250 RPM 25klb	Recommend 500 psi differential across MWD for telemetry	5,000 lbs/min (e.g., 333 gpm @ 15.0 ppg)	None	MWD Generator	Application specific	Yes
3/23/3/56	Y	Negative pulse from surface skid unit	0	0	250 bit RPM 55klb	Recommend 500 psi differential across MWD for telemetry	10,000 lbs/min (e.g., 1,000 gpm @10 ppg)	None	Lithium batteries	Application specific	Yes
3/23/3/56	Y	Negative pulse from surface skid unit	0	0	250 bit RPM 55klb	Recommend 500 psi differential across MWD for telemetry	10,000 lbs/min (e.g., 1,000 gpm @10 ppg)	None	Lithium batteries	Application specific	Yes
3/23/3/58	Y	Negative pulse from surface skid unit	0	0	250 bit RPM 90klb	Recommend 500 psi differential across MWD for telemetry	12,000 lbs/min (e.g., 1,200 gpm @10 ppg)	None	Lithium batteries	Application specific	Yes
3/23/3/58	Y	Negative pulse from surface skid unit	0	0	250 bit RPM 90klb	Recommend 500 psi differential across MWD for telemetry	12,000 lbs/min (e.g., 1,200 gpm @10 ppg)	None	Lithium batteries	Application specific	Yes
N/A	Y	Pipe Rotation	4-8 minutes	45 deg.	220 RPM / 30klbs	N/A	300	None	Fully Mechanical	1. Short Gauge Length 2. Active Gauge Cutting Structure 3. >= 350 psi pressure drop	No
Inc / Azm 12.8 / 12.8	Y	Flow rate change	While drilling ahead	0	350 RPM 55 klbf	290	800	50 lb/bbl med. nut plug	Turbine generator	Application specific - bi-center compatible	Modular
Inc / Azm 16.7 / 16.7	Y	Flow rate change	While drilling ahead	0	350 RPM 75 klbf	450	1,800	50 lb/bbl med. nut plug	Turbine generator	Application specific - bi-center compatible	Modular
Inc / Azm 8.8 / 10.9 GR 8.0	Y	Flow rate change	While drilling ahead	0	220 RPM 65 klbf	300	2,000	50 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
Inc / Azm 8.4 / 10.5 GR 7.6	Y	Flow rate change	While drilling ahead	0	220 RPM 65 klbf	300	2,000	50 lb/bbl med. nut plug	Turbine generator	Application specific	Modular

2015 Rotary steerable drilling systems directory

Product trade name	Point-the-bit or Push-the-bit?	Length (ft)	O. D. & I. D. (inches)	Hole size (inches)	Max DLS capability (°/100')	Automated closed loop deviation control (yes/no) (+/-degrees)	Build rate increment	Is deviation force continuous?	Max temp (°C /°F)	Max internal pressure (psi)	Other special pressure limitations	Require configuration based on anticipated flow rate?
PowerDrive X6 825	Push	13.84	OD: 8.25 ID: N/A	10.625 - 11.625	6	Yes +/- 0.1°	1% and 1° TF resolution	Adjustable	150/302 (175/350 optional)	25000 (35,000 Optional)	Adjustable within a 200 psi pressure range at the bit	Yes
PowerDrive X6 675	Push	13.47	OD: 6.75 ID: N/A	8.5 - 9.875	8	Yes +/- 0.1°	1% and 1° TF resolution	Adjustable	150/302 (175/350 optional)	25000 (35,000 Optional)	Adjustable within a 200 psi pressure range at the bit	Yes
PowerDrive X6 475	Push	13.65	OD: 4.75 ID: N/A	5.5 - 6.75	8	Yes +/- 0.1°	1% and 1° TF resolution	Adjustable	150/302 (175/350 optional)	25,000	Adjustable within a 200 psi pressure range at the bit	Yes
PowerDrive Archer 675	Hybrid-Point-the-Bit	16.6	OD: 6.75 ID: N/A	8.375 - 8.75	15	Yes +/- 0.1°	1% and 1° TF resolution	Adjustable	150/302	25,000	Optimized for Drilling conditions	Yes
PowerDrive Archer 475	Hybrid-Point-the-Bit	15	OD: 4.75 ID: N/A	5.875 - 6.75	18	Yes +/- 0.1°	1% and 1° TF resolution	Adjustable	150/302	25000	Optimized for Drilling conditions	Yes
PowerDrive Orbit 900 Large Borehole	Push	14.27	OD: 9.625 ID: N/A	16 - 18.5	3	Yes +/- 0.1°	1% and 1° TF resolution	Adjustable	150/302	25000 (35,000 Optional)	Adjustable within a 400 psi pressure range at the bit	Yes
PowerDrive Orbit 900	Push	14	OD: 9.625 ID: N/A	12.25 - 14.75	5	Yes +/- 0.1°	1% and 1° TF resolution	Adjustable	150/302	25000 (35,000 Optional)	Adjustable within a 400 psi pressure range at the bit	Yes
PowerDrive Orbit 675	Push	13.53	OD: 6.75 ID: N/A	8.5	8	Yes +/- 0.1°	1% and 1° TF resolution	Adjustable	150/302 (175/350 optional)	25000 (35,000 Optional)	Adjustable within a 400 psi pressure range at the bit	Yes
PowerDrive Orbit 475	Push	13.5	OD: 4.75 ID: N/A	5.75 - 6.125	8	Yes +/- 0.1°	1% and 1° TF resolution	Adjustable	150/302 (175/350 optional)	25,000	Adjustable within a 400 psi pressure range at the bit	Yes
PowerDrive ICE	Push	34.26	OD: 6.75 ID: N/A	8.5	8	Yes +/- 0.1°	1% and 1° TF resolution	Adjustable	200/392	30,000	Adjustable within a 400 psi pressure range at the bit	Yes
Weatherford Daniel Villa, Global Service Line Manager - RSS Daniel.Villa@la.weatherford.com www.weatherford.com												
Revolution 950 rotary steerable system (Core, Heat, V)	Point	24.89	OD: 9.50 ID: 2.75	12.00 - 26.00	6	Yes	Variable	Yes	149/300 Core, V 175/347 Heat	25,000 Core, V 30,000 Heat	None	No
Revolution 825 rotary steerable system (Core, Heat, V)	Point	17.8	OD: 8.25 ID: 2.75	18.25 - 10.625	7.5	Yes	Variable	Yes	149/300 Core, V 175/347 Heat	25,000 Core, V 30,000 Heat	None	No
Revolution 675 rotary steerable system (16)	Point	20.18	OD: 6.75 ID: 2.0	8.375 - 9.875	16	Yes	Variable	Yes	149/300 175/347 optional	25,000	None	No
Revolution 675 rotary steerable system (Core, Heat, V)	Point	14.8	OD: 6.75 ID: 2.0	8.375 - 9.875	10	Yes	Variable	Yes	149/300 Core, V 175/347 Heat	25,000 Core, V 30,000 Heat	None	No
Revolution 475 rotary steerable system (Core, Heat, V)	Point	12.9	OD: 4.75 ID: 1.75	5.875 - 6.75	10	Yes	Variable	Yes	149/300 Core, V 175/347 Heat	25,000 Core, V 30,000 Heat	None	No
Revolution 475 rotary steerable system (SRT)	Point	63.94	OD: 4.75 ID: 1.25	5.875 - 6.75	3 rotating to 12° sliding	Yes	Variable (Can slide at any time to achieve higher build rates)	Yes	165/350 operating	30,000	requires drilling motor	No
Revolution 6.5 rotary steerable system (SRT)	Point	64.5	OD: 6.50 ID: 2.00	7.875	3 rotating to 12° sliding	Yes	Variable (Can slide at any time to achieve higher build rates)	Yes	165/350 operating	30,000	requires drilling motor	No
Revolution 675 rotary steerable system (SRT)	Point	64.99	OD: 6.75 ID: 2.00	8.5 - 9.875	3 rotating to 12° sliding	Yes	Variable (Can slide at any time to achieve higher build rates)	Yes	165/350 operating	30,000	requires drilling motor	No
Revolution 825 rotary steerable system (SRT)	Point	65.42	OD: 8.25 ID: 2.75	10.625 - 12.250	3 rotating to 12° sliding	Yes	Variable (Can slide at any time to achieve higher build rates)	Yes	165/350 operating	30,000	requires drilling motor	No

	Sensor distance (ft) Inc/Azm/GR/Res	Control from surface (Downlink)? (Y / N)	If yes, tool control method	Req'd to communicate change in target (minutes)	Minimum kickoff inclination (degrees)	Max RPM / WOB	Min flow rate (gpm)	Max flow rate (gpm)	LCM limits	Power source	Bit requirements	Integrated LWD?
	Inc / Azm 8.4 / 10.5 GR 7.6	Y	Flow rate change	While drilling ahead	0	220 RPM 65 klbf	300	2,000	50 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
	Inc / Azm 7.3 / 9.4 GR 6.4	Y	Flow rate change	While drilling ahead	0	220 RPM 65 klbf	200	950	50 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
	Inc / Azm 6.7 / 8.8 GR 5.9	Y	Flow rate change	While drilling ahead	0	220 RPM 50 klbf	100	380	35 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
	Inc / Azm 9.9 / 12.1 GR 9.7	Y	Flow rate or RPM change	While drilling ahead	0	350 RPM As per Smith PDC bit guidelines	250	650	50 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
	Inc / Azm 8.2 / 10.4 GR 7.4	Y	Flow rate or RPM change	While drilling ahead	0	350 RPM As per Smith PDC bit guidelines	220	350	35 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
	Inc / Azm 8.47 / 10.67 GR 7.67	Y	Flow rate change AND Collar RPM Variation	While drilling ahead	0	350 RPM 65 klbf	350	2,000	50 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
	Inc / Azm 8.24 / 10.44 GR 7.44	Y	Flow rate change AND Collar RPM Variation	While drilling ahead	0	350 RPM 65 klbf	350	2,000	50 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
	Inc / Azm 7.56 / 9.76 GR 6.76	Y	Flow rate change AND Collar RPM Variation	While drilling ahead	0	350 RPM 56 klbf	250	950	50 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
	Inc / Azm 7.06 / 9.16 GR 6.16	Y	Flow rate change AND Collar RPM Variation	While drilling ahead	0	350 RPM 14.5 klbf	170	330	35 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
	Inc / Azm 13.30/13.30 GR 16.70	Y	Flow rate change AND Collar RPM Variation	While drilling ahead	0	350 RPM 56 klbf	275	800	50 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
	19/19/21/48	Y	Drillstring rotation or negative pulse from surface skid unit	Typically < 3	0	250 RPM 90 kib	No minimum requirement	1,800	Steering system: None MWD system: 80 lb/ bbl fine/med (higher conc. on request)	Lithium batteries	Long passive gauge PDC	Yes
	14/14/16/42	Y	Drillstring rotation or negative pulse from surface skid unit	Typically < 3	0	250 RPM 90 kib	No minimum requirement	1,500	Steering system: None MWD system: 80 lb/ bbl fine/med (higher conc. on request)	Lithium batteries	Long passive gauge PDC	Yes
	16/ 16/18/44	Y	Drillstring rotation or negative pulse from surface skid unit	Typically < 3	0	250 RPM 50 kib	No minimum requirement	750	Steering system: None MWD system: 80 lb/ bbl fine/med (higher conc. on request)	Lithium batteries	Long passive gauge PDC	Yes
	12/ 12/14/40	Y	Drillstring rotation or negative pulse from surface skid unit	Typically < 3	0	250 RPM 50 kib	No minimum requirement	750	Steering system: None MWD system: 80 lb/ bbl fine/med (higher conc. on request)	Lithium batteries	Long passive gauge PDC	Yes
	9/ 9/16/39	Y	Drillstring rotation or negative pulse from surface skid unit	Typically < 3	0	250 RPM 25 kib	No minimum requirement	350	Steering system: None MWD system: 80 lb/ bbl fine/med (higher conc. on request)	Lithium batteries	Long passive gauge PDC	Yes
	40/40/44/70	Y	Drillstring rotation or negative pulse from surface skid unit	Typically < 3	0	350 RPM 25 kib	150	360	Steering system: None MWD system: 80 lb/ bbl fine/med (higher conc. on request)	Lithium batteries	Long passive gauge PDC	Yes
	40/40/44/71	Y	Drillstring rotation or negative pulse from surface skid unit	Typically < 3	0	350 RPM 60 kib	200	500	Steering system: None MWD system: 80 lb/ bbl fine/med (higher conc. on request)	Lithium batteries	Long passive gauge PDC	Yes
	40/40/44/70	Y	Drillstring rotation or negative pulse from surface skid unit	Typically < 3	0	350 RPM 70 kib	200	600	Steering system: None MWD system: 80 lb/ bbl fine/med (higher conc. on request)	Lithium batteries	Long passive gauge PDC	Yes
	40/40/44/73	Y	Drillstring rotation or negative pulse from surface skid unit	Typically < 3	0	250 RPM 90 kib	300	900	Steering system: None MWD system: 80 lb/ bbl fine/med (higher conc. on request)	Lithium batteries	Long passive gauge PDC	Yes

Red Hawk stands as first spar ever decommissioned in GoM

The VB 10,000 is shown during topsides float over. (Photo courtesy Anadarko)

Sarah Parker Musarra
Editor

The Red Hawk spar made history throughout its design life, commissioned and decommissioned as the first of its kind. Heralded as the first cell spar ever built, it remains the lone cell spar ever fabricated just slightly 10 years after its inception. Decommissioned in September 2014, it then earned distinction of being the deepest floating production unit to be retired in the Gulf of Mexico.

The Technip-built cell spar was originally designated for use in the Red Hawk gas field, located in 5,300 ft (1,615 m) of water in the GoM's Garden Banks block 876. It was a third-generation spar pioneered by an Anadarko predecessor, Oklahoma City-based Kerr-McGee, and was brought into production just 24 months after sanctioning, when the first of two of the Red Hawk gas field's subsea wells began producing in July 2004. Red Hawk field was estimated by the operator to have a resource base of 250 bcf of natural gas. Located less than 200 mi (322 km) away from several other developments in which the company held interests, including the Boomvang, Nansen, and Gunnison fields, it was designed to be a hub for future projects, lowering the economic margin for development.

Part of that economic feasibility was due to its design of the spar itself, explained Ryan Kavanagh, facilities engineer for Anadarko. The Red Hawk spar, which measured 64 ft (19 m) in diameter and was 560-ft (170-m) long, comprised of six tubes, all connected by structural steel, and all surrounding the final, seventh tube. The tubes were 20 ft (6 m) in diameter.

Such a design allowed the fabrication to be carried out domestically, rather than in Europe, as had most other spars. The Red Hawk spar components were manufactured in several different yards in Texas, which significantly saved cost. Kavanagh said that the tech-



The Red Hawk spar was the first to be decommissioned in the Gulf of Mexico. (Photo courtesy InterMoor)

nology used was "closely-aligned to industry-proven jacket fabrication techniques," so local fabrication was a strong option.

What made it possible was the ability to take plate and roll it into tubular, cylindrical sections, Kavanagh explained, which was used for pile and jacket fabrication in all different diameters. "It's the rolling of a steel plate into a can ... whereas you don't roll a spar hull that's just a classic spar or a truss spar," he noted.

Additionally, its design, already notable for its size, made the spar notable for something else. Up until the Red Hawk spar, one primary use for deployment was their ability to use dry trees.

"This was the first wet tree-only spar, which proves that the spar technology could be economic even when you didn't need it for the dry tree benefits that it offered," Kavanagh explained. FMC Technologies performed the subsea work, including the creation of the spar's enhanced horizontal 10,000-psi trees.

Having successfully produced the targeted resources, Red Hawk's wells, along with its spar, went offline in 2008, with the wells being P&A'd in 2011.



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Decommissioning and reefing

Kavanagh said that Anadarko explored a variety of options before deciding to decommission Red Hawk prior to Anadarko's lease expiry on the block in 2012. Reusing the facility on another field was not deemed feasible. The unit had also been made prior to the string of Category 5 hurricanes that ripped through the Gulf of Mexico, so should it be re-purposed, modifications would have been necessary. Nobody wanted to scrap a years-old facility.

Therefore, the Red Hawk spar, the GoM's deepest facility to ever be decommissioned, continues to produce even in retirement: It was decided that the structure would be reefed in Eugene Island block 384, off Louisiana. It now functions as a marine life habitat.

Early planning for the decommissioning began in 2011. Kavanagh said that Anadarko worked with several regulatory agencies involved with the Bureau of Safety and Environmental Enforcement's Rigs to Reefs program. Laid on its side, the spar would be an ideal candidate, and would even improve the natural environment of the GoM in some regards.

"Actually, one of the things that most excited the Louisiana Wildlife and Fisheries team about the spar becoming an artificial reef was because of the soft, sandy bottom of the Gulf of Mexico. It doesn't have a lot of cavernous, hard surfaces for marine ecosystems to develop on," he said. "The spar would be able to create a really unique habitat in the Gulf of Mexico, something that they can study in the future and see what kind of positive impacts it has, and how that will impact the future projects."

Anadarko and its contractors began to mobilize, including InterMoor, the project's main contractor, whose scope of work included engineering, offshore work, decommissioning, towing, ballasting and deballasting, mooring disconnect/recovery, and reefing.

The decommissioning work would take place during a 24-day period in the heart of hurricane season, between August and September 2014. Kavanagh said that planning for a decommissioning was more than just considering the project simply the opposite of a commissioning.

"It's different mentally and emotionally to have something one day and know that the next day it's gone; you won't have it anymore," he said.

Versabar's *VB 10,000*, a fully-automated DP-3 barge-mounted dual truss system, was used for the removal of the 3,800-ton (3,447 metric ton) topsides. The company says it is the largest lift vessel to be built in the US, with a hook height of 178 ft (54 m) and a lift capacity of 7,500 tons (6,803 metric tons). Versabar says that it was the first time the *VB 10,000* had performed a lift on a floating facility. The topsides were floated, which meant that there were two independent floating structures, something else that required much planning and engineering.

Todd Veselis, general manager, Permanent Moorings for InterMoor, said that because the topsides were removed completely, workers had to ballast the hull down exceptionally low – down to



Deballasting following topsides removal. (Photo courtesy Anadarko)

around 15-20 ft (4-6 m) of freeboard, he said— so that the *VB 10,000* could completely lift the topsides off and to transport them for recycling.

Additionally, the entire operation had to be storm-safe. Nobody could wait for perfect weather in the hurricane-prone GoM to perform any part of the decommissioning. For example, deck legs, which took one day each to cut through, were pre-cut and then re-attached with a temporary clip, albeit one strong enough for a 10-year GoM hurricane, Kavanagh said,

noting that the company worked with agencies including the Coast Guard and other agencies to ensure that these implements were necessarily robust.

Decommissioning the Red Hawk spar, with its unique air-over-water ballasting system, would represent InterMoor's first time to work in ballasting and deballasting.

"We had to engineer a separate, remote ballasting system to be able to facilitate the top-side lift," Veselis explained. "Then, once the topsides were gone, we had to deballast the hull so that we could finish the mooring disconnect; then eventually tow to the reefing site; set it on bottom; and then do the actual reefing."

Of course, InterMoor also had to plan for the spar's rapidly-diminishing parts and pieces. With the mooring system running from the topsides, much engineered preparation was necessary prior to the lift. The six-point mooring system led to one work chain. InterMoor cut the work chain into three sections and attached

these to the mooring chains on one side of the hull. The mooring lines were then slacked three to one side prior to topsides removal.

That alleviated tension for the entire system, Veselis explained. It also allowed for topsides removal and formed as the basis for the removal of the mooring.

After *VB 10,000* removed the topsides, another vessel was called in to assist with removing the spar: McDermott's *Derrick Barge 50*, a DP-2 heavy-lift and lowering vessel. Veselis said it acted as a staging area throughout the operation, in addition to ballasting, towing, reefing and mooring disconnect, accommodation, and support services.

The spar hull was ballasted back up, and *DB 50* removed the spar hull, with *Kirt Chouest* remaining behind for mooring recovery.

Veselis saw the Red Hawk spar as a lifetime project: InterMoor, as a predecessor company, was involved with the installation, and he was a project engineer on the original installation. That information, along with the companies' pre-existing relationship, helped operations run smoothly.

Kavanagh said that during the peak of decommissioning, there were more than 300 workers offshore spread out across multiple vessels.

"With a few minor exceptions, including weather delays, the operation ran smoothly, which is credited to a comprehensive planning phase," he explained. "A great deal of practical experience was gained through the decommissioning of Red Hawk that will be applied to future projects both for Anadarko and the industry." ●



The *VB 10,000* removes the Red Hawk cell spar's topsides. (Photo courtesy InterMoor)

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Deepwater construction vessel provides improved stability, novel pipelay

Jeremy Beckman
Editor, Europe

Recently, the two main cranes and vertical lay system (VLS) were fitted on Ceona's new deepwater field development vessel *Ceona Amazon* at the Huisman yard in Schiedam, the Netherlands.

The 199.4-m (654-ft) long vessel, which will be the flagship of Ceona's growing fleet, is designed to perform in multiple pipelay and operational modes, including heavy lift and subsea construction. Its large storage areas allow it to carry 5,500 tons of flexible pipe or 8,500 tons of rigid pipe, with further storage space available on the 4,600-sq m (49,514-sq ft) main deck. This combination allows the vessel to carry sufficient quantities of rigid and flexible pipe, risers, umbilicals, or subsea structures (depending on requirements) to execute logistically complex projects in remote environments in a single trip, the company claims, minimizing the need for support cargo barges.

Lloydwerft constructed the hull at its shipyard in Bremerhaven, northern Germany. The hull is the third of a series of a proven drillship design – the others were commissioned by Noble Drilling. Ceona selected this concept because of its beneficial verified vessel response characteristics. The mid-ship moonpool is located close to the vessel's transverse axes, minimizing the impact of the vessel's motions on pipe stresses during installation. This should allow the vessel to remain in operation in relatively heavy seas and strong winds, Ceona claims. Additionally, the 8 x 13.5-m (26 x 44-ft) moonpool can accommodate the largest pipeline end termination structures.

Huisman designed and built *Ceona Amazon*'s 570-metric ton (628-ton) top tension VLS tower, an upgraded version of a tower used by Technip on the *Deep Blue*, and also the twin 400-metric ton (441-ton) active heave compensated cranes. These are capable of operating in tandem to lower large subsea structures, as well as handling long and complex subsea spools. In addition, the cranes can be used to support installations of mooring spreads for FPSOs, semisubmersible platforms, and TLPs.

Most of these features are derived from proven technologies, although the combination of the various components is unparalleled, Ceona claims. One new feature is the vessel's G-lay pipelay system (patent pending), which again combines tried-and-tested components and procedures. According to a presentation by the company's design engineering lead Jay Nguyen at the Deep Offshore Technology Conference in Aberdeen last year, the welding line is traditional S-lay. However, following welding the pipe is deflected around a stern wheel and installed through a conventional pipelay tower with two tensioners and 570-ton top tension in water depths of up to 3,000 m (10,000 ft).

To verify the functionality and capability of the proposed lay spread, the design team defined an "analysis roadmap" – an eight-point

sequence of activities. The first was a beam element pull-through study to estimate the level of deck tension required as pipe is pulled through the system, and the maximum loads that will be applied on the stern wheel and tower wheel. This involved building a finite element (FE) model of the system, with the tower in the vertical position and the stern wheel shifted as far as possible to produce the largest free span. Analysis suggested sag and stress in the free span will reduce as deck tension increases, at the same time allowing the pipe to conform closer to the wheel profiles.

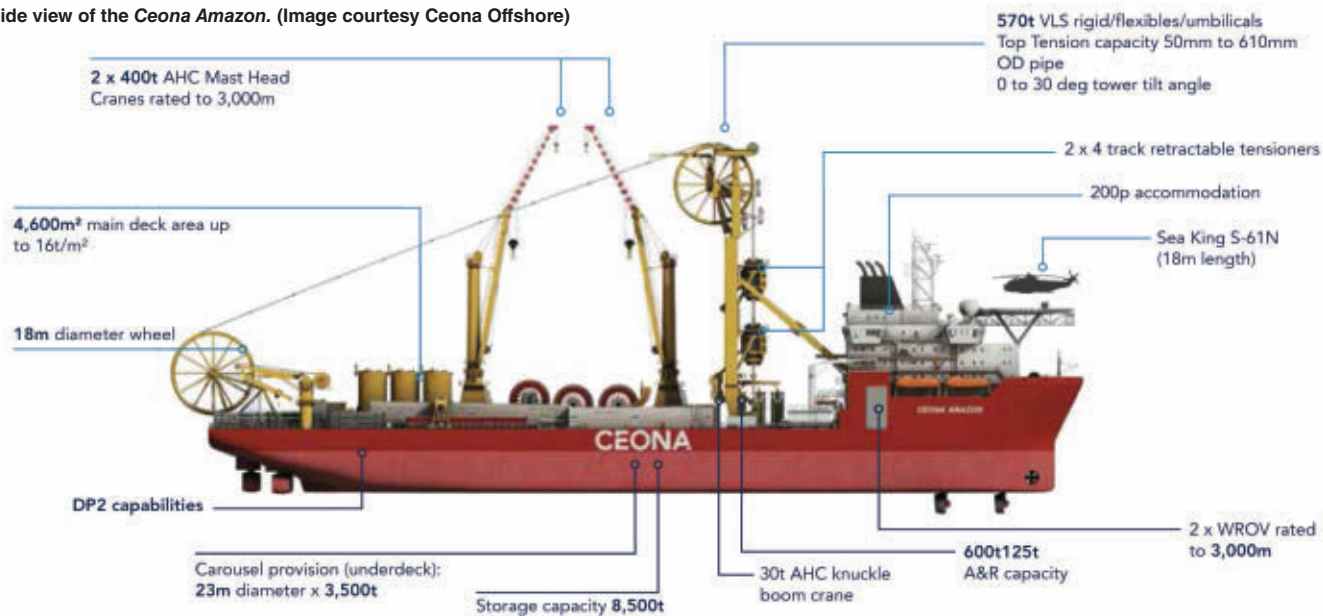
The company then developed a shell element FE model to assess pipe buckling potential followed by a parametric study to consider a range of uncoated, homogeneous pipes with varying outer diameters as they are pulled through the lay system. Shell elements were used to model each pipe type to allow observation of pipe ovalization as the pipe is pulled through the system. Results suggested buckling would not be an issue, with peak strain during pipelay occurring in the pipe's outermost fiber as it is pulled around the lay wheels, with a marginal ovalization of each pipe as it is bent around the tower wheel.

The next step was to establish whether a heavily insulated pipe could be bent around the aft wheel. The main concerns were quantifying the impact of bare field joints on the reeling process, and the effect of the geometric and material discontinuity on the ovality of the pipe close to these joints. The company analyzed a range of pipe diameters and wall thicknesses, including a syntactic



The *Ceona Amazon* with a newly fitted crane at the Huisman yard in Schiedam, the Netherlands. (Photo courtesy Ceona Offshore)

Side view of the Ceona Amazon. (Image courtesy Ceona Offshore)



polyurethane foam heavy insulation in thicknesses of 50, 75, and 100 mm. To optimize the model, the pipe string was revised to two coated pipe joints with the bare field joint centered, connected to beam elements modeling the remaining part of the pipe string. Then Ceona extended the complexity of the

models beyond just shell elements for the study to quantify the impact of bare field joints. For this, they built the models using brick elements to obtain more accurate results during the pipe plastification stages of the process. Results suggested a heavy insulation coating will lead to increased ovaliza-

tion of the pipe in the bare field joint region, compared with an uncoated pipe, underlining the importance of assessing property mismatches. Ceona has taken measures to mitigate localized ovality in a separate study.

Analysis of the realistic pipe pull-through was then performed to determine the sys-

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tem's sensitivity to property mismatches between pipe joints, arising from variation in the manufacturing process. The study considered the impact of a variation in material yield strength, pipe wall thickness and yield to tensile ratio between adjoining pipe sections, with a back tension of 500 kN applied to represent the tension normally applied to each pipe by the deck tensioner. It involved modeling a 24.4-m (80-ft) brick element pipe length to represent two typical joint lengths, but of differing material properties to model mismatch.

One conclusion was that the mismatches result in increased ovalization in the bare field joint region, an effect most pronounced for wall thickness and yield strength mismatches. Another was that the pipe is more sensitive to ovalization when its leading length (pulled around the aft wheel first) has greater material strength or section modulus, compared with the trailing section. The company will use the results to define a full installation envelope and detailed pipelay assessment specific to each project the vessel performs.

During installation of a rigid pipeline, the pipe will be unsupported within the free span between the vessel's aft and tower wheel and also when in the catenary during installation. To determine the acceptability of these

known free spans, Ceona conducted analyses of environmental loading and vessel motions in relation to the pipe's fatigue life. These suggested that fatigue would be greatest when the vessel is exposed to prolonged periods of beam seas, with wave heights at or above the vessel's weather installation limit. In practice, the company will take into account metocean data, pipe material, and joint weld properties for each individual project.

Then followed simulated bend trials, in collaboration with Cladtek International, of a range of 8-in. nominal bore carbon steel pipes of varying composition to assess strain behavior and also how deformation of the pipe wall develops during the bending process. Findings were then compared with computer simulations and finite element analysis (FEA) models of the system.

Results suggested generally good correlation. Ceona commissioned an FE software specialist to develop a parametric tool to create individual cases for homogeneous pipe, each with a specified outer diameter, wall thickness and axial tension, and also to redefine the parameters and modeling conditions specific to each pipe configuration. The resultant products reduced the time taken to construct each model from hours to less than a minute. Further software followed, developed in-house

and by consultants, to extract required data for ovality, stresses and strains in the model, allowing a time history to be compiled as the pipe is pulled through the vessel's lay spread.

Finally, Ceona commissioned an independent verification of the lay system, results of which were virtually identical to the company's own FE modeling. Ceona claims comparative FEA modeling of a conventional lay spread indicates pipe ovalization similar to results for the *Ceona Amazon*. It will devise future test schedules to define a full installation envelope and detailed pipelay assessment specific to each project.

The company plans to pitch the vessel for relatively short-term construction jobs, particularly in the deepwater Atlantic triangle region. It has been designed to reach speeds of up to 14 knots, with the 28-MW MAN-supplied power plant providing 20% better fuel efficiency than some competing vessels, according to Mark Preece, executive vice president for commercial and business development.

This was Lloydwerft's first offshore construction job. The shipyard was looking to build an offshore track record and was able to offer a competitive price, Preece said. "We are happy with the quality of the vessel and its workability, and the quality of their supply chain has been outstanding." ●



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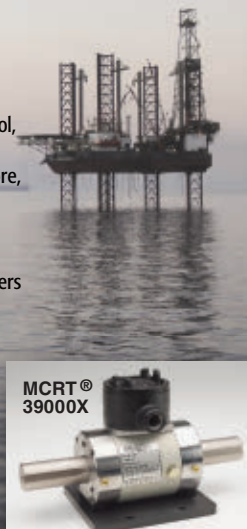
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Lewek Constellation heads to the Gulf of Mexico

Sarah Parker Musarra
Editor

EMAS AMC has introduced the *Lewek Constellation*, a unique vessel that finds itself in an increasingly unique situation. By the time it hits the waters of the Gulf of Mexico in April, the subsea construction vessel will have a backlog of work worth more than \$500 million with a \$120-million West African job already completed.

It is literally unique in that it is one of two vessels in its class, according to EMAS AMC, achieving the highest notations in both environmental and comfort classes. At nearly 180 m (591 ft) long, *Lewek Constellation* is a DP-3 ice-classed, multi-lay offshore construction vessel with ultra-deepwater pipelay and heavy-lift capabilities.

Christened and officially named on March 1 from Huisman Equipment's facility in the Netherlands, *Lewek Constellation* was conceived in 2009. However, two acquisitions made by EMAS AMC, the subsea unit of Ezra Holdings Ltd., greatly contributed to the design that would become *Lewek Constellation* by giving the newly-augmented company experience in critical areas, explained Steve Louis, EMAS AMC's vice president of Engineering.

In 2011, the Singapore-based company acquired Aker Marine Contractors (AMC), which was the subsea umbilicals, risers, and flowlines (SURF) and floater installation unit of Aker Solutions. At that time, it also entered into a 50/50 joint venture for the ownership and chartering of *AMC Connector* (now *Lewek Connector*), a 2012-built multi-purpose construction vessel valued at approximately \$300 million.

"The acquisition of AMC established EMAS as a formidable umbilical installation contractor," Louis said, explaining that the new company's first project was in the Tamar field off Israel for Noble Energy, which also awarded *Lewek Constellation* its second contract.

A few years later in 2013, he continued, the company picked up exclusive charters for the s-lay *Caesar* (now *Lewek Centurion*) and the reel-lay *Express* (now *Lewek Express*) from Helix Energy Solutions Group, also acquiring Helix's 120-acre marine spoolbase facility in Ingleside, Texas.

"This enabled EMAS AMC to provide onshore rigid pipe construction and offshore pipelay installation services for our clients to complement our umbilical installation capabilities," Louis said. "The *Lewek Constellation* is the consummation of years of developing a high-spec, full-field development vessel fueled by a best-in-class workforce who possess the knowledge and expertise in SURF construction and heavy-lift operations."

It was important to EMAS AMC that its flagship vessel stay consistent with its company strategy, which was to differentiate itself from its competition through improved technology and high-spec vessels. Louis said he was confident that the vessel achieved this, noting that it was purposefully designed with a good mix of equipment, offering ultra-high top tension equipment, with ultra-high crane capacity, and ultra-deep ROVs.

"We believe that strategy is about choosing the right mix of technology in order to create a unique and valuable position for our clients and the *Lewek Constellation* is the vessel that epitomizes that belief," he said.

Lewek Constellation has taken features from similar vessels and super-sized them. For example, the vessel has a 3,000-metric ton (3,306-ton) Huisman Offshore mast crane, compared to the 400-metric ton (441-ton) crane offered by most competitors. It also has a Huisman multi-lay system capable of installing rigid and flexible pipe up to 800 metric tons (882 tons) of top tension and 1,200 metric tons (1,322 tons) of abandonment and recovery system. It also houses two Schilling HD work-class ROVs



Lewek Constellation during its 800-metric ton Huisman multi-lay system installation at the Huisman Equipment quayside facility. (Photo courtesy Huisman Equipment)

that are rated for 4,000-m (13,123-ft) for inspection, repair, maintenance, intervention, and construction work. (Incidentally, *Lewek Constellation* also sports a large 19-m by 8-m (62-ft by 26-ft) moonpool.)

What is immediately apparent upon viewing *Lewek Constellation* sets it apart as unique: a distinct removable reel system, which the company believes makes the vessel ideal for remote fields. It can travel alongside a barge and allow for offshore reel transfer, saving the vessel trips to and from a spoolbase.

In October 2014, the vessel successfully completed its inaugural installation project, a job for VAALCO Gabon (Etame) Inc., offshore Gabon. The work scope included the transportation and installation of two jackets, topsides, flare booms, and living quarters for the Etame and Southeast Etame/North Tchibala platforms. It also installed new living quarters and a gas lift package onto the FPSO *Nautipa*.

It then headed to Huisman's yard in the Netherlands to be fitted for its multi-lay tower and ancillary equipment.

Having departed the Netherlands on March 13, *Lewek Constellation* is now headed to the GoM to begin work on a passel of contracts signed with Noble Energy, including the engineering, procurement, construction, and installation of subsea tiebacks for the Big Bend, Dantzler, and Gunflint projects. A total of more than 80 mi (130 km) of pipe-in-pipe flowlines and more than 56 mi (100 km) of umbilicals in water depths up to 7,200 ft (2,200 m) is included in the project scope of *Lewek Constellation*'s first deepwater pipelay.

"They provide us the challenge; we provide the solution," Louis said of EMAS AMC's relationship with the Houston-based operator.

In October 2014, more than \$70 million of work was booked in multiple contract awards from "a variety of national oil companies, oil majors, and contractors" in the GoM and Asia/Pacific, EMAS AMC said. Its most recent contract was in January 2015, when it signed a procurement, fabrication, and subsea installations with Apache Energy to work off Australia in 1Q 2016.

Louis said that EMAS AMC being a start-up put the wheels in motion for *Lewek Constellation*'s success.

"[Start-ups] have to be different, to raise that bridge between innovation and proven, predictable improvement," he said. ●

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Industry advances deepwater production riser technology

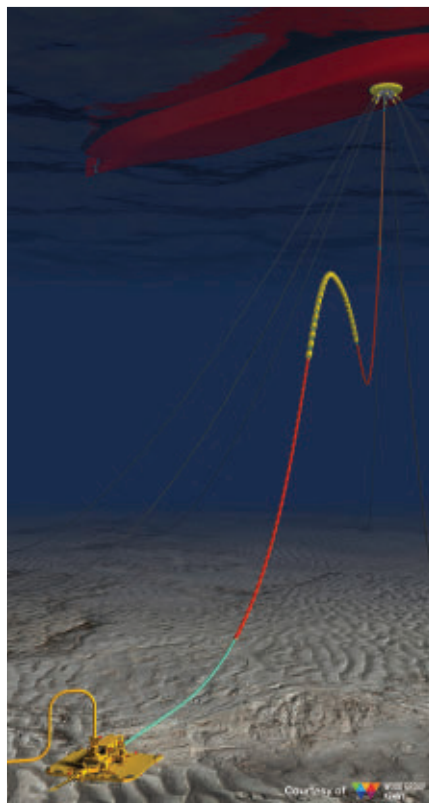
Johann Melillo
Wood Group Kenny

This issue of *Offshore* magazine includes an update to the Deepwater Production Riser Systems & Components Poster. Nearly five years have passed since the last edition of this poster was published, and there have been several advances related to riser technology over this short period of time.

Most of the advances are due to the constant push to develop oil fields in deeper waters, and with higher temperatures and pressures. The three traditional manufacturers of unbonded flexible pipe using metallic armor wires, GE Oil & Gas, NOV, and Technip, have all qualified risers up to and beyond 2,000 m (6,562 ft) water depth. Flexible pipes have to date been installed in water depths up to about 2,250 m (7,382 ft). However, a limitation of these traditional unbonded flexible pipe designs is the requirement for additional tensile armor wires to withstand the higher tensile loads due to deeper waters and longer riser lengths. This means more steel area and more steel armor wires to withstand this load, which in turn means additional weight. Hence, all the manufacturers are now starting to develop pipe designs with lighter composite and carbon fiber armor wires.

In terms of temperature, all unbonded flexible pipe manufacturers now offer designs with PVDF internal pressure sheaths qualified up to 130°C (266°F), and one manufacturer recently qualified its PVDF sheath up to 150°C (302°F). In discussing pressure, a useful method to determine the limits of flexible pipes is to use the term design pressure x ID, for example using the units psi-in. This is because the larger the internal diameter of the pipe, the more challenging is the design for a higher pressure rating. The approximate industry limit is about 70,000 psi-in. This would mean a 4-in. ID pipe rated to 17,500 psi (121 MPa) or a 16-in. pipe rated to 4,375 psi (30 MPa). There are already some installed riser examples beyond this limit, e.g., 7.7-in. pipe with a design pressure of 10,000 psi (77,000 psi-in.), 12-in. pipe with a design pressure of 6,525 psi (78,300 psi-in.), and also 10-in. pipe with a design pressure of 8,526 psi (85,260 psi-in.).

Advances in technology can also be witnessed in steel riser design. Similar to unbonded flexible risers, there is a drive for larger diameter steel catenary risers (SCRs) in deeper waters and solutions able to withstand higher pressures and temperatures. Cladding and Inconel welding techniques have advanced to



The first steel lazy wave risers in the Gulf of Mexico were installed at the Anadarko-operated Caesar-Tonga development. (Photo courtesy Wood Group Kenny)

provide better protection against corrosion. In terms of diameter, the present industry limits are 24-in. SCRs installed at fields such as Holstein, Mad Dog, Thunder Horse, and Atlantis. A number of SCRs have also been installed in water depths up to about 2,400 m (7,874 ft) such as at Perdido and Independence Hub.

Probably the most significant advance for steel risers in recent years has been the development of steel lazy wave risers (SLWRs) which allow a better fatigue performance and the ability to use steel risers on projects where a “simple” SCR is not technically feasible. The first SLWRs in the Gulf of Mexico were installed at Caesar-Tonga. Shell is planning to use SLWRs in order to develop what will be the deepest field in the world. The Stones development is in a water depth of about 2,900 m (9,514 ft). The use of SLWR technology at Stones will enable the steel risers to be hung-off an FPSO with a disconnectable turret.

It is also worthwhile to mention that hybrid risers have also been proved feasible for ultra-deepwater developments. The most notable example is the Cascade-Chinook development which made use of free-standing hybrid risers to enable the first FPSO development in the Gulf of Mexico in a water depth of about 2,500 m (8,202 ft).

Thus the use of hybrid risers as well as the development of SLWRs provides riser solutions for the industry as it looks to exploit reserves in even deeper waters. With the development of lighter unbonded flexible pipes, flexible pipes might also soon become a feasible solution for water depths in excess of 2,500 m (8,202 ft).

Riser ancillary components have also seen major advances to keep up with the demand for deeper water as well as higher temperature and pressure applications. The Deepwater Production Riser Systems & Components Poster lists some examples of new concepts and emerging technologies in Table 1. A few examples are further highlighted here:

- The combination of greater water depths and increased buoyancy module volumes has demanded significant upgrading of foam systems for buoyancy modules. Balmoral has developed lower density foams under its trademark Superlite-X and Durafoam HT names that allow the use of buoyancy modules for drilling and production risers at water depths beyond 3,000 m (9,842 ft).
- Thermal insulation materials are also becoming more sophisticated in order to cope with higher temperatures and hydrostatic pressures. Trelleborg Offshore's Vikotherm S1 thermal insulation is based on non-syntactic silicone technology and is designed for operating temperatures between -40°C to 135°C (-40°F to 275°F) and depths up to 3,000 m (9,842 ft).
- Oil States has continued developing its ancillary components for steel risers. The Gen-2 FlexJoint technology provides extended service life at high-pressure/high-temperature conditions. In addition, the Oil States diverless Barracuda rigid riser pull-in connector, SLWR I-tube hang-off adaptors and integrated FlexJoint collet-connector units for submerged buoy SCR installation are enabling the use of steel risers for new applications such as deployment off disconnectable turrets. ●



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APRIL 2015

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ACKNOWLEDGEMENT OF THE CONTRIBUTORS:

WoodGroup/Kenny and Offshore magazine wish to acknowledge the following individuals and companies who continue to support our efforts to educate and inform the oil & gas industry on the status of deepwater production riser technology.

2H Offshore: Mike Campbell, Tim Eyles; **AF Global Corporation:** Christine Mathews; **Aker Solutions:** Roger Lu, John Nustad, Kate Winterford; **Balmoral:** Stephen Gibe; **DeepFlex:** Jessica Kneer; **INTEDEC:** Diane Bailey; **NOV:** Joachim Christensen, Rusty De La Fuente, Stein Rilde, Allison Habibovic, Lene Lykke Mesager; **ODI Status:** Brian McDermott, Darlene Morris; **Safeps:** Fabio Perrone; **SBM Offshore:** Nicolas Florin-Olivier; **Technip:** Inge Ekegren, Steven Jan, Sarah Prindemast, Claire Yu; **TrellisOffshore Offshore:** Ruth Gray; **Xodus Solutions:** Nicola Cowie.

Information Accuracy: We have attempted to use correct and current, as of press time, information for the tier systems and components described herein. No installed, sanctioned, nor pending application was intentionally excluded. We have summarized the capability and operating experience by acting as a neutral party and integrator of information. Information has been collected from public sources, company brochures, personal interviews, phone interviews, press releases, industry magazines, vendor-supplied information, and web sites. No guarantee is made that information is

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A2	AL2	AL3	AL4	AL5	AL6	AL7	AL8	AL9	AL10	AL11	AL12	AL13	AL14	AL15	AL16	AL17	AL18	AL19	AL20	AL21	AL22	AL23	AL24	AL25	AL26	AL27	AL28	AL29	AL30	AL31	AL32	AL33	AL34	AL35	AL36	AL37	AL38	AL39	AL40	AL41	AL42	AL43	AL44	AL45	AL46	AL47	AL48	AL49	AL50	AL51	AL52	AL53	AL54	AL55	AL56	AL57	AL58	AL59	AL60	AL61	AL62	AL63	AL64	AL65	AL66	AL67	AL68	AL69	AL70	AL71	AL72	AL73	AL74	AL75	AL76	AL77	AL78	AL79	AL80	AL81	AL82	AL83	AL84	AL85	AL86	AL87	AL88	AL89	AL90	AL91	AL92	AL93	AL94	AL95	AL96	AL97	AL98	AL99	AL100
A2	AL2	AL3	AL4	AL5	AL6	AL7	AL8	AL9	AL10	AL11	AL12	AL13	AL14	AL15	AL16	AL17	AL18	AL19	AL20	AL21	AL22	AL23	AL24	AL25	AL26	AL27	AL28	AL29	AL30	AL31	AL32	AL33	AL34	AL35	AL36	AL37	AL38	AL39	AL40	AL41	AL42	AL43	AL44	AL45	AL46	AL47	AL48	AL49	AL50	AL51	AL52	AL53	AL54	AL55	AL56	AL57	AL58	AL59	AL60	AL61	AL62	AL63	AL64	AL65	AL66	AL67	AL68	AL69	AL70	AL71	AL72	AL73	AL74	AL75	AL76	AL77	AL78	AL79	AL80	AL81	AL82	AL83	AL84	AL85	AL86	AL87	AL88	AL89	AL90	AL91	AL92	AL93	AL94	AL95	AL96	AL97	AL98	AL99	AL100
A2	AL2	AL3	AL4	AL5	AL6	AL7	AL8	AL9	AL10	AL11	AL12	AL13	AL14	AL15	AL16	AL17	AL18	AL19	AL20	AL21	AL22	AL23	AL24	AL25	AL26	AL27	AL28	AL29	AL30	AL31	AL32	AL33	AL34	AL35	AL36	AL37	AL38	AL39	AL40	AL41	AL42	AL43	AL44	AL45	AL46	AL47	AL48	AL49	AL50	AL51	AL52	AL53	AL54	AL55	AL56	AL57	AL58	AL59	AL60	AL61	AL62	AL63	AL64	AL65	AL66	AL67	AL68	AL69	AL70	AL71	AL72	AL73	AL74	AL75	AL76	AL77	AL78	AL79	AL80	AL81	AL82	AL83	AL84	AL85	AL86	AL87	AL88	AL89	AL90	AL91	AL92	AL93	AL94	AL95	AL96	AL97	AL98	AL99	AL100
A2	AL2	AL3	AL4	AL5	AL6	AL7	AL8	AL9	AL10	AL11	AL12	AL13	AL14	AL15	AL16	AL17	AL18	AL19	AL20	AL21	AL22	AL23	AL24	AL25	AL26	AL27	AL28	AL29	AL30	AL31	AL32	AL33	AL34	AL35	AL36	AL37	AL38	AL39	AL40	AL41	AL42	AL43	AL44	AL45	AL46	AL47	AL48	AL49	AL50	AL51	AL52	AL53	AL54	AL55	AL56	AL57	AL58	AL59	AL60	AL61	AL62	AL63	AL64	AL65	AL66	AL67	AL68	AL69	AL70	AL71	AL72	AL73	AL74	AL75	AL76	AL77	AL78	AL79	AL80	AL81	AL82	AL83	AL84	AL85	AL86	AL87	AL88	AL89	AL90	AL91	AL92	AL93	AL94	AL95	AL96	AL97	AL98	AL99	AL100
A2	AL2	AL3	AL4	AL5	AL6	AL7	AL8	AL9	AL10	AL11	AL12	AL13	AL14	AL15	AL16	AL17	AL18	AL19	AL20	AL21	AL22	AL23	AL24	AL25	AL26	AL27	AL28	AL29	AL30	AL31	AL32	AL33	AL34	AL35	AL36	AL37	AL38	AL39	AL40	AL41	AL42	AL43	AL44	AL45	AL46	AL47	AL48	AL49	AL50	AL51	AL52	AL53	AL54	AL55	AL56	AL57	AL58	AL59	AL60	AL61	AL62	AL63	AL64	AL65	AL66	AL67	AL68	AL69	AL70	AL71	AL72	AL73	AL74	AL75	AL76	AL77	AL78	AL79	AL80	AL81	AL82	AL83	AL84	AL85	AL86	AL87	AL88	AL89	AL90	AL91	AL92	AL93	AL94	AL95	AL96	AL97	AL98	AL99	AL100
A2	AL2	AL3	AL4	AL5	AL6	AL7	AL8	AL9	AL10	AL11	AL12	AL13	AL14	AL15	AL16	AL17	AL18	AL19	AL20	AL21	AL22	AL23	AL24	AL25	AL26	AL27	AL28	AL29	AL30	AL31	AL32	AL33	AL34	AL35	AL36	AL37	AL38	AL39	AL40	AL41	AL42	AL43	AL44	AL45	AL46	AL47	AL48	AL49	AL50	AL51	AL52	AL53	AL54	AL55	AL56	AL57	AL58	AL59	AL60	AL61	AL62	AL63	AL64	AL65	AL66	AL67	AL68	AL69	AL70	AL71	AL72	AL73	AL74	AL75	AL76	AL77	AL78	AL79	AL80	AL81	AL82	AL83	AL84	AL85	AL86	AL87	AL88	AL89	AL90	AL91	AL92	AL93	AL94	AL95	AL96	AL97	AL98	AL99	AL100
A2	AL2	AL3	AL4	AL5	AL6	AL7	AL8	AL9	AL10	AL11	AL12	AL13	AL14	AL15	AL16	AL17	AL18	AL19	AL20	AL21	AL22	AL23	AL24	AL25	AL26	AL27	AL28	AL29	AL30	AL31	AL32	AL33	AL34	AL35	AL36	AL37</																																																															

Figure 1 - Alternatives / New Concepts of Riser Systems & Components:



Figure 3: Top Tension Rivers (TTR) and Stand Category Rivers (SCR) with TLR

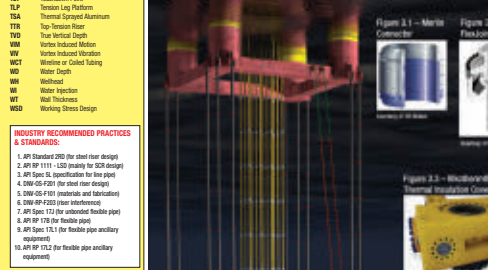


Figure 4 - Top-Tension Rivets with SPAR

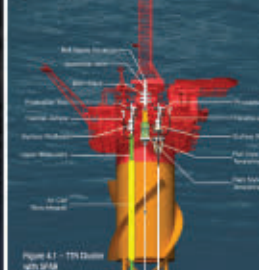
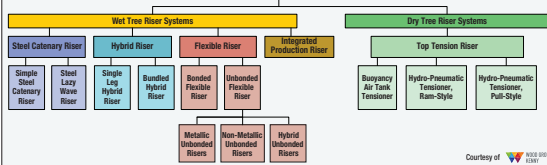


Figure 6 - Steel Lazy Mow Riser (SLMR)



Chart 2 – RISER SYSTEMS



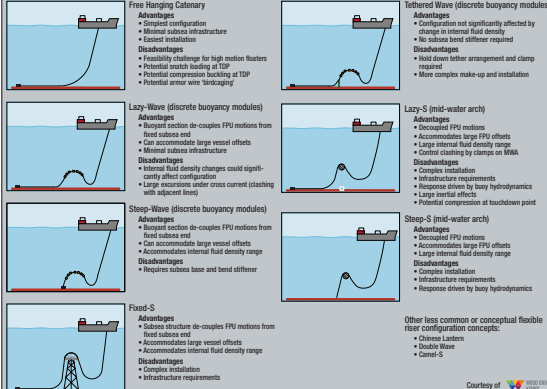
Courtesy of  NCOB
KENNY

Table 3 – Riser System Options

Riser Types		Production Platform Types					
		Compliant Tower	TLP	SPAR	SEMI	FP/SO - Non Cyclic Em.	FP/SO - Cyclic Em.
1.0 Wet Tree Riser Systems							
1.1	Steel Catenary Riser						
	1.1.1 Simple Steel Catenary Riser	●	●	●	●	●	NA
	1.1.2 Steel Lary Wave Riser	●	●	●	●	●	●
Hybrid Riser							
1.2	1.2.1 Single Leg Hybrid Riser	●	●	●	●	●	●
	1.2.2 Bundled Hybrid Riser	●	●	●	●	●	●
Flexible Riser							
1.3	1.3.1 Bonded Flexible Pipe	●	●	●	●	●	●
	Unbonded Flexible Riser						
	1.3.2.1 Metallic Unbonded Risers	●	●	●	●	●	●
	1.3.2.2 Non-Metallic Unbonded Risers	●	●	●	●	●	●
	1.3.2.3 Hybrid Unbonded Risers	●	●	●	●	●	●
	1.3.3 Integrated Production Riser	●	●	●	●	●	●
2.0 Dry Tree Riser Systems							
2.1	Top Tension Riser						
	2.1.1 Buoyancy Air Tank Tensioner	●	●	●	●	NA	NA
	2.1.2 Single-Pneumatic Tensioner Beam Style	●	●	●	●	NA	NA
	2.1.3 Hydro-Pneumatic Tensioner Pull Style	●	●	●	●	NA	NA

● Installed ● In Development ● Conceptual / Potentially Feasible

Figure 2 - Flexible Riser Configurations

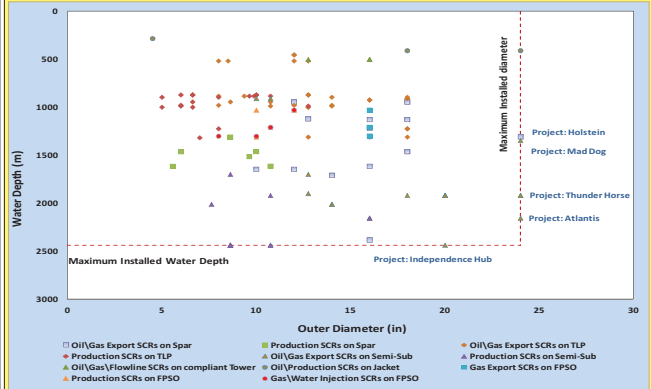


Other less common or conceptual flexible riser configuration concepts:

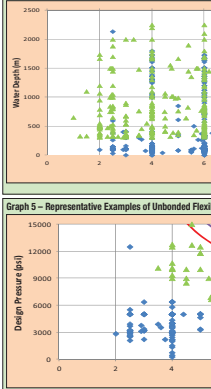
- Chinese Lantern
- Double Wave
- Camel-S

Courtesy of  VIBRO ENGINEERING

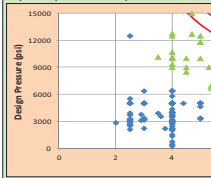
Graph 1 – Representative Examples of Steel Catenary Risers (SCRs)



Graph 4 – Representative Examples of Unbonded Flex



Graph 5 – Representative Examples of Unbonded Flexi



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Table 1 - Alternatives / New Concepts of Riser Systems & Components

Table 1 - Alternatives / New Concepts of Riser Systems & Components								NOV 2006
#	COMPANY	CONCEPT NAME/TYPE	STAGE OF DEV (1)	PLATFORM TYPE (2)	DAMETER (mm)	WATER DEPTH (m)	INSTALLATION METHOD (3)	
1	Offshore Subsea 7	Grouped Single Line Offshore riser			2,200	1,600 - 3,000		
2	Offshore Subsea 7	Grouped Single Line and TIE System Deep Subseasables		Sea	2,200	500 - 1,000	IL	
3	Offshore Subsea 7	Grouped Single Line and TIE System Deep Subseasables		Sea	2,200	500 - 1,000	IL	
4	INTERTECH Weyburn Paraffin Gelsol	TTH with coils, Tension Leg Platform (TLP)	C	Sea	TTH up to 14"	500 - 1,000	IL	
5	INTERTECH Weyburn Paraffin Gelsol	TTH with coils, Tension Leg Platform (TLP)	C	Sea	TTH up to 14"	500 - 1,000	IL	
6	INTERTECH Weyburn Paraffin Gelsol	Single Horizontal Riser with FPSO	C	Sea	2,200	500 - 1,000	J	
7	INTERTECH Weyburn Paraffin Gelsol	Single Horizontal Riser with FPSO	C	Sea	TTH 8, 10R	1,000 - 2,000	J	
8	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
9	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
10	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
11	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
12	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
13	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
14	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
15	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
16	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
17	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
18	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
19	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
20	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
21	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
22	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
23	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
24	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
25	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
26	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
27	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
28	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
29	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
30	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
31	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
32	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
33	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
34	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
35	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
36	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
37	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
38	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
39	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
40	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
41	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
42	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
43	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
44	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
45	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
46	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
47	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
48	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
49	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
50	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
51	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
52	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
53	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
54	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
55	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
56	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
57	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
58	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
59	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
60	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
61	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
62	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
63	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
64	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
65	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
66	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
67	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
68	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
69	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
70	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
71	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
72	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
73	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
74	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
75	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
76	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
77	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
78	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
79	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
80	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
81	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
82	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
83	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
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98	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
99	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	
100	INTERTECH Weyburn Paraffin Gelsol	TTH Riser concept for TLP	C	Sea	2,200	500 - 1,000	J	

1) Field Proven (F), Model Tested/Material Tested (M), Conceptual (C) 2) T-P (T), Semi-Gal, Saw-Gal, Ship (S) 3) Pipeline (P), J-Lay (J), Drill Rig (DR), Towing (T), S-Lay (S)

Chart 1 – COMPANIES WITH SUBSEA RISER SYSTEMS AND COMPONENTS

[illegible]

Courtesy of  WOODWARD-CLYFF

Figure 6 – Hybrid Steel Catenary Production Semi-Saltwater Site

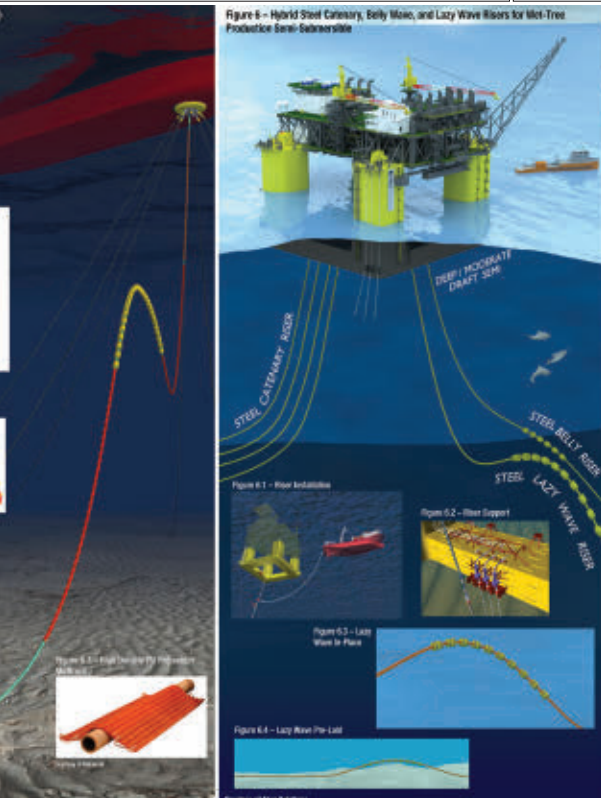


Figure 7 - Field-of-View with Disconnects - Target F90

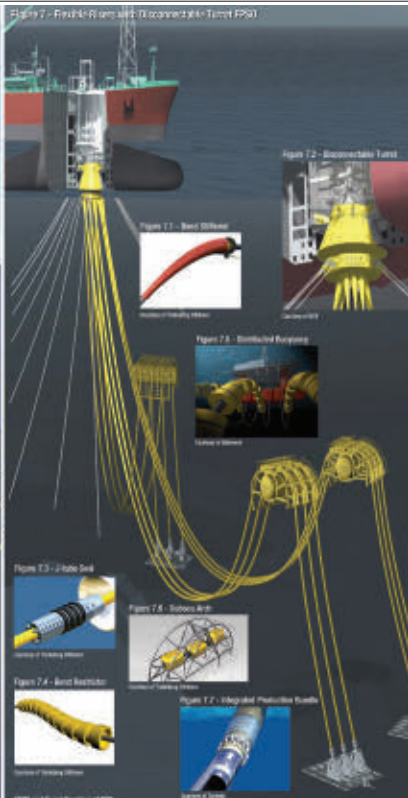
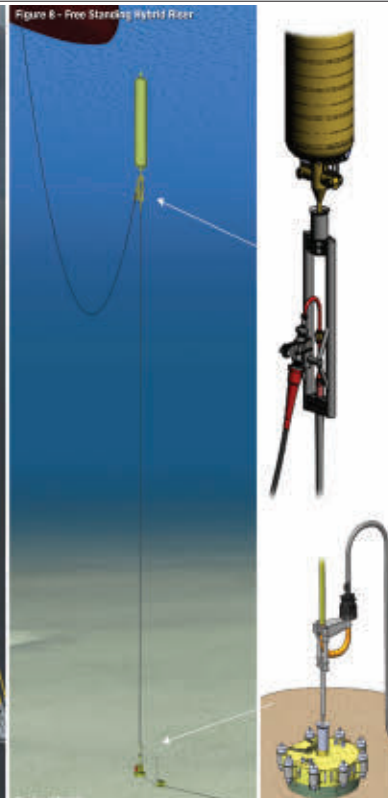


Figure 8 - Free Standing Hybrid Rise



Variable Risers, showing Water Depth Capability

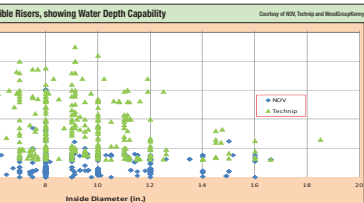


Table Risers, showing Design Pressure Capability

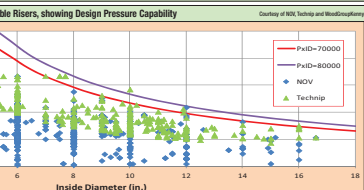


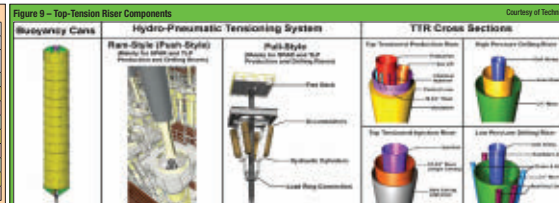
Table 4 – Technology Status of Unbonded Flexible Risers

Name	Status	Specification									
		Max Allowable Water Depth (m)			Max Inside Diameter (in)			Max Allowable Pressure (Mpa)			
		WD (m)	Assumed (ft)	Max. Depth (m)	D (in)	Assumed (in)	D (in)	Pressure (Mpa)	Assumed (in)	Max. Pressure (Mpa)	
Deepflex	Installed	1,500	3.5	10	9	200	70	27	3.5	60	
	Qualified	3,000	7	120	12	500	90	69	7	120	
	Estimating	3,500	10	130	16	1,000	120	104	8	130	
NOV	Installed	1,750	6	130	16.6	300	130	43	12	130	
	Qualified	2,000	4	130	16	500	130	50	12	130	
	Estimating	2,500	10	130	16	1,000	130	130	6	150	
Technip	Installed	2,250	8	130	19	300	130	138	4	130	
	Qualified	3,000	9	130	20	500	150	138	6	150	
	Estimating	3,000	12	170	22	500	170	120	9	170	

Table 5 – Representative Examples of Hybrid Risers

Name	Region	Type	Water Depth (m)	Year Installed	Status	Operators	Floating Platform Type	# of Towers/Risers
West Africa								
Girassol	Angola	Bundle	1,350	2001	Operating	Exxon	Spread Moored FPSO	3
Kizomba A	Angola	Single Line	1,005 – 2,000	2004	Operating	Enxan	Spread Moored FPSO	3
Kizomba B	Angola	Single Line	1,005 – 2,000	2004	Operating	Enxan	Spread Moored FPSO	—
BP Ezeris Platform	Angola	Bundle	1,311	2007	Operating	BP	Spread Moored FPSO	1
	Angola	Bundle	1,311	2007	Operating	BP	Spread Moored FPSO	1
	Rosa	Angola	1,380	2007	Operating	Total E&P	Spread Moored FPSO	1
CL2V	Angola	Bundle / Single Line	1,050 – 4,100	2011	Operating	Total	Spread Moored FPSO	3
	Angola	Single Line	1,150	2011	Operating	Total E&P	Spread Moored FPSO	4
Kizomba Satellites	Angola	Single Line	2,100	2012	Operating	BP	turret Moored FPSO	8

Figure 9 – Top-Tension Riser Components



Emerging markets to drive FPU construction over near term

Through the end of the decade, the largest markets for floating production systems are expected to remain in Brazil, West Africa, and Southeast Asia. However, there are new areas of growth, particularly in East Africa and the Mexican portion of the Gulf of Mexico.

The fastest growing segment is forecast to be gas processing units, namely FLNGs and FSRUs, which are expected to account for 25% of all floating production systems capex over the next five years.

However, oil processing units, especially FPSOs, will continue to be the dominant type of floating production systems worldwide. FPSOs are expected to account for 45% of the projected orders and 60% of the capex. Floating production systems are defined here to include FLNGs, FPSOs, FSOs, FSRUs, semi-submersibles, spars, and TLPs.

Five-year forecast

Between 105 to 188 floating production systems are expected to be built over the next five years with a total capital cost between \$80.2 and \$157.4 billion. The most likely forecast is 142 orders costing \$118.5 billion. Units for Brazil and Africa will account for \$48 billion of expenditure, followed by \$30 billion in Australia and South-

David Boggs
*Energy Maritime
Associates Pte. Ltd.*

east Asia, and over \$25 billion in the Gulf of Mexico and Northern Europe. Significant growth is expected toward the end of the decade in Mexico as international companies enter the market.

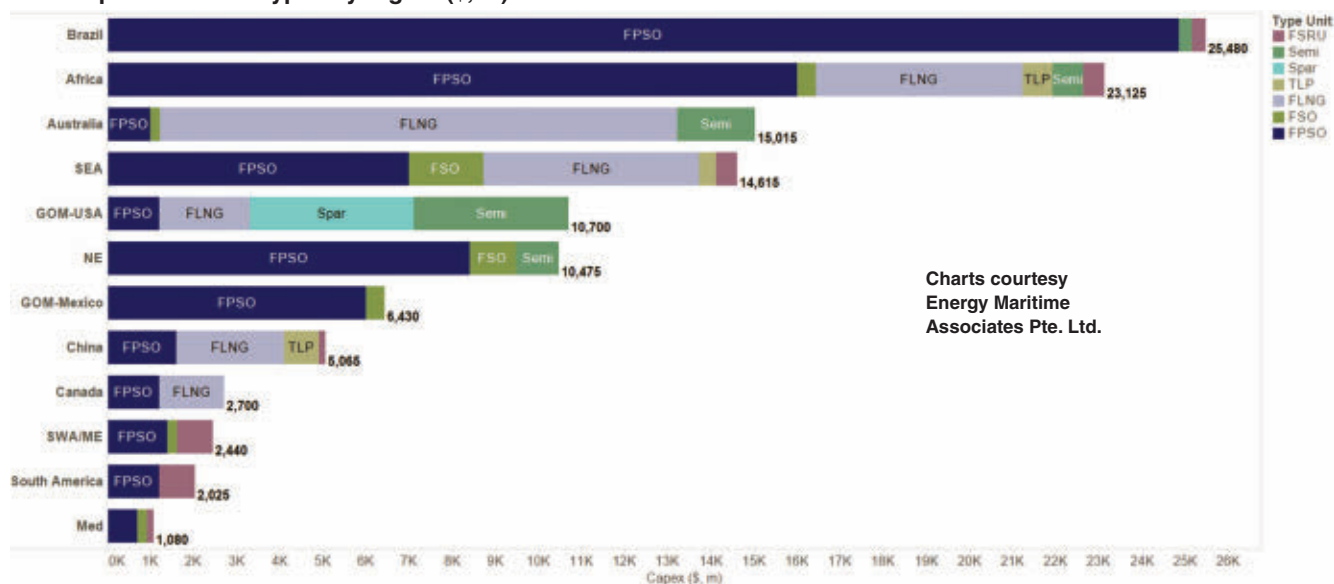
Brazil and Africa should continue to attract the most capital investment over the next five years. Over \$25 billion is the best case estimate for Brazil, driven by FPSOs for Petrobras. Africa is a close second with \$23 billion of spending mainly on FPSO and FLNG projects. Approximately \$15 billion will be spent in floater projects in Australia and Southeast Asia. Australia investments are dominated by large gas FLNGs and semis, while Southeast Asia has a mix of FPSOs, FLNGs, and FSOs. Projects for the US GoM and Europe are expected to cost around \$10 billion, mostly on FPSOs in the North Sea. Units for the US GoM are spread amongst FPSOs, FLNG export terminals, spars, and production semis. A new growth area for the next five years is the Mexican side of the GoM, where \$6.4 billion is expected to be spent on FPSOs and FSOs.

Brazil

FPSOs will account for almost all of the new units expected over the next five years in Brazil. Most, but not all, will be for Petrobras. The Brazilian state-owned company had planned to award at least 14 new floating production contracts over the next three years. However, this is unlikely to happen on schedule given the investigations and financial issues surrounding the company. There will be a delay in these awards, so we do not expect to see many contracts placed by Petrobras in 2015. However, the presalt fields have proven to be viable and additional FPSOs will be required for development. According to Petrobras and its partner BG, the break-even for many of these fields is \$45/bbl.

Two non-Petrobras projects that could require FPSOs include Phase 2 of Queiroz Galvao's heavy-oil Atlanta development in block BS-4 and Karoon's Kangaroo discovery. In December 2014, Teekay was awarded a three + two year lease contract to redeploy the *Petrojarl 1* FPSO for Phase 1 development of the Atlanta field. A larger FPSO with up to 80,000 b/d processing capacity could be required for the full field development. A redeployed FPSO could also be a viable solution for the Kangaroo field.

Total capex of all FPS types by region (\$, m) based on best case 2015-2019 forecast.





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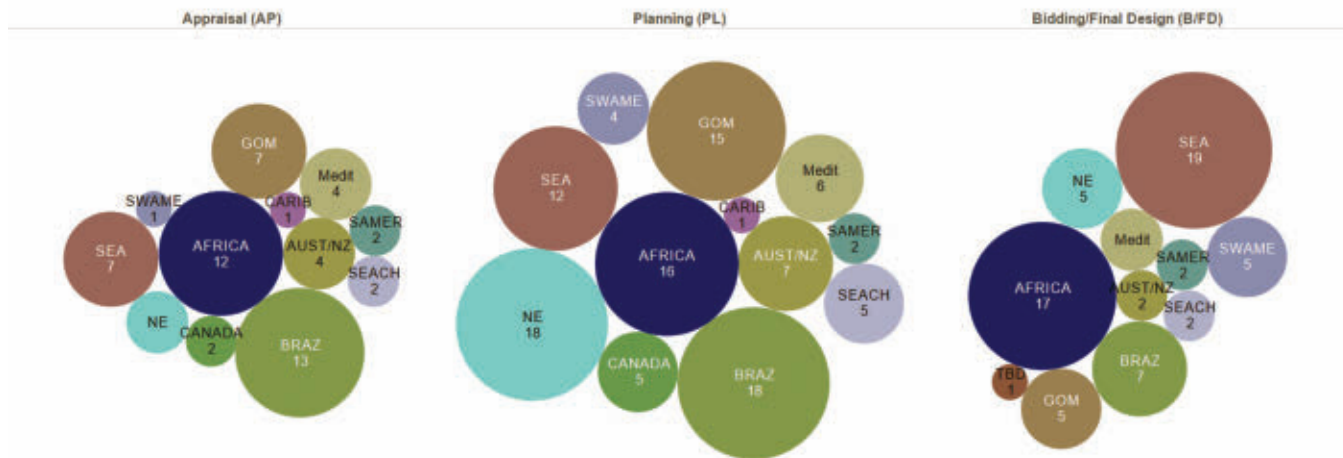


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Projects under appraisal, planning, and bidding/final design stage by region.



Africa

The vast majority of projects in Africa will continue to be located on the west coast, particularly off Angola and Nigeria. However, floating production units are also being used in new areas. Ghana received its first FPSO for Tullow's Jubilee field in 2010. Tullow selected Modec to provide another FPSO for the nearby TEN development, which is scheduled to begin production in 2016. In January 2015, Yinson was awarded a 15-year FPSO lease contract by Eni for its Sankofa/Gye Nyame development. Potential new projects in Ghana include an FPSO for the ultra-deepwater Tano Cape Three Points field and an FSRU as part of a natural gas-fired power plant development.

There are no floating production units in operation or on order for East Africa, but this is set to change with seven projects currently being planned. All of these are natural gas developments – three off Mozambique, three off Tanzania, and one off Kenya. BG is investigating use of multiple TLP units for its deep-water fields in Tanzania's block 1 (Mzia and Jodari) and block 4 (Pweza, Chewa, Ngisi). In Mozambique, a front-end engineering and design (FEED) competition is in progress for an FLNG unit to develop Eni's Coral gas fields in Area 4. In order to achieve first production by 2019, an award would be required in 2015. After Coral, Eni has plans for two additional FLNG units and an onshore plant to monetize Area 4's Mamba discoveries. An FSRU could be required as part of Kenya's Dongo Kundu power project.

Australia/New Zealand

Large FLNG units are expected to account for 75% of the capital cost for projects in Australia over the next five years. This includes Woodside's Browse development, which calls for three units. FEED is now planned to start by mid-2015 with final in-

vestment decision targeted for 2016. No new floating production systems are expected in New Zealand in the near future, although there has been some recent exploration activity.

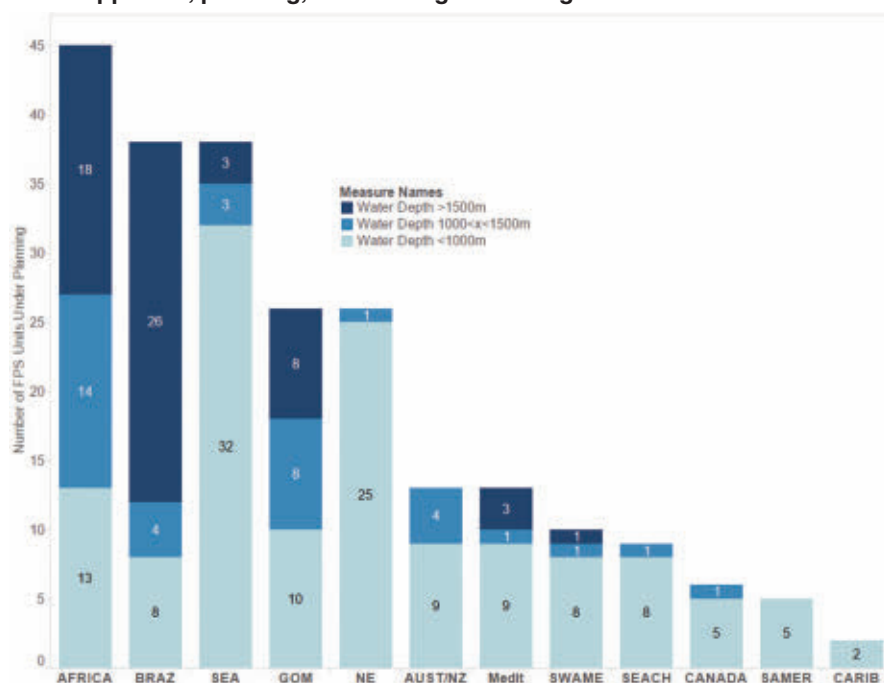
Southeast Asia

Despite the drop in oil prices, a number of projects are moving ahead in Southeast Asia. Hess recently awarded an FSO contract for its North Malay Basin project, which will process gas on a fixed platform and send condensate to the FSO. Kris Energy is progressing plans for its block A development offshore Cambodia, after taking

over operatorship from Chevron in 2014. Projects are expected to be tendered later this year include a TLP and FPSO for Talisman's Red Emperor field off Vietnam and three projects off Indonesia – Premier Oil's Ande Ande Lumut FPSO, Husky's Madura MDA/MBH Production Barge, and possibly the third tender for Chevron's Gendalo/Genham production barges.

Over the next five years, more than \$5 billion in capex is expected for various FLNG projects in Southeast Asia, particularly the Abadi field development in Indonesia. A 2.5 mtpa FLNG facility is planned for Phase 1, which is completing FEED. Another facil-

Water depth of current projects under appraisal, planning, and bidding/final design.



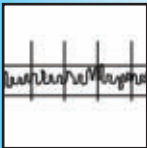
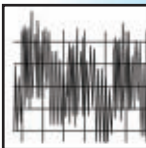
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ity would be required for Phase 2, which is scheduled to enter FEED this year.

US GoM

A mix of FPSOs, production semisubmersibles, spars, and FLNG units will account for \$10 billion of investment. At least eight FLNG projects have been proposed, but most are not likely to move forward in the near future. SBM Offshore is scheduled to deliver an FPSO for Shell's Stones development in 2016. This will be the second FPSO on the US side of the Gulf of Mexico and the deepest floating production unit – moored in 2,900 m (9,514 ft) of water. Another FPSO could be required by the end of the decade for BP's Kaskida field, located in 1,800 m (5,905 ft) of water in block KC 292.

However, there has been a recent trend toward tiebacks to existing facilities in the US Gulf, including Noble's Big Bend and Dantzer fields, ExxonMobil's Hadrian gas field, and Chevron's deepwater Buckskin/Moccasin development. Tieback to an existing asset can provide a faster and less expensive alternative to a stand-alone facility, depending on the distance, capacity, and charges of the host facility.

Mexican GoM

Following the reforms in Mexico, there will certainly be an increase in the number of floating production units from the one FSO and one FPSO currently in operation, in addition to a few small well testing units. However, this will take time. After the new leases are granted, it will take at least two to three years before contracts are placed for these new facilities. PEMEX began discussions for two FPSOs in 2013, but has yet to place the contract. These would be leased units – a very large unit for the Ayatsil/Tekel field and a dynamically positioned unit to perform extended well tests in various locations.

Northern Europe

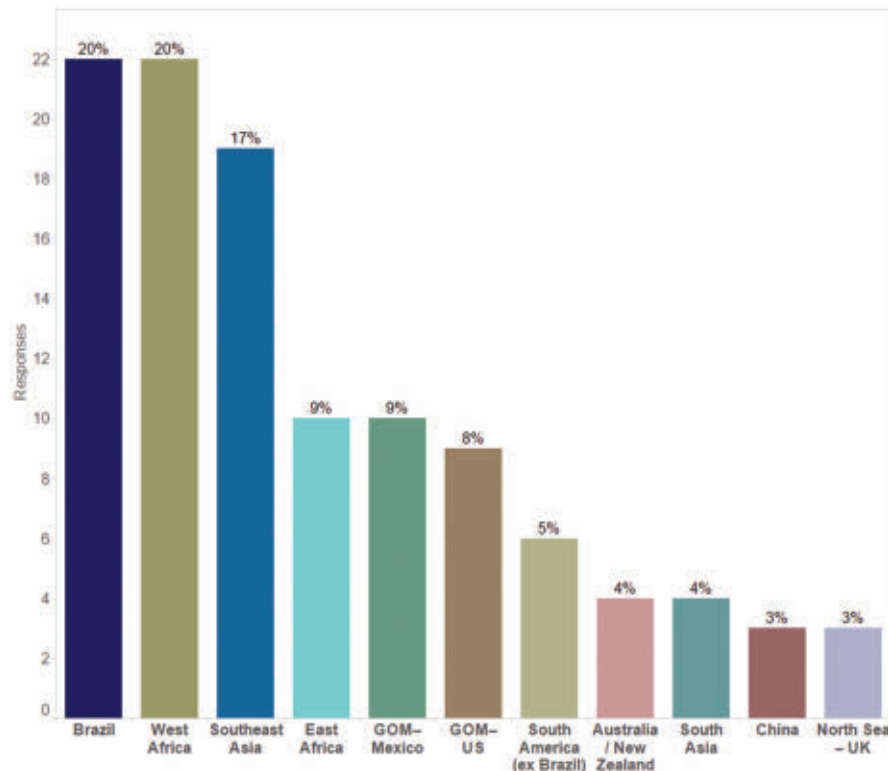
Twenty-six projects are in the planning phase in Northern Europe, predominantly the UK and Norway. FPSOs are the likely solution for 80% of developments, with 20% using FSOs and production semisubmersibles. Only two new floating production projects were sanctioned in 2014, down from three in 2013 and four in 2011 and 2012. This is largely due to increasing costs, which have forced review for new developments including Rosebank in the UK and Johan Castberg in Norway.

There has been much discussion of production from the Arctic. While there are interesting prospects in areas farther north of current facilities, we do not expect to see any arctic floating production units before the end of the decade.

Planning pipeline

Energy Maritime Associates (EMA) has identified 235 projects that potentially could

What regions or countries will present the largest growth opportunities over the next five-10 years?



require a floating production system. These projects are declared discoveries or planned developments where a floating production or storage system could be a development option. Since last year, there have been declines in the number of viable projects off Africa, Brazil, and Southwest Asia. These are predominantly deepwater fields with insufficient recoverable resources. However, these declines have been offset by new potential projects in the North Sea, Gulf of Mexico, and Southeast Asia.

By level of development

Of these 235 potential projects, 29% are in the bidding/final design stage, with Africa and Southeast Asia the most active regions. Final investment decisions and contract awards for these projects are possible in the next 12-24 months. 46% of projects are in the planning stage. A number of these projects from northern Europe, Gulf of Mexico, and Brazil have yet to move to the bidding/final design stage due to technical complexity and regulatory environment. The final 25% are in the appraisal stage, predominantly deepwater discoveries in Brazil and Africa.

By water depth

Before 2000, almost all floating production units were located in less than 1,000 m (3,280 ft) of water. Since 2010, over half of new units

are located in more than 1,000 m, including 30% in more than 1,500 m (4,921 ft). For projects in the planning pipeline, 59 projects (25%) are in ultra-deepwater and 38 projects (16%) are in water depths of 1,000 to 1,500 m. The remaining 138 projects (61%) are in less than 1,000 m. Brazil and Africa account for the vast majority of deepwater projects – 63% of projects located in more than 1,000 m waters are in these two areas.

Many of the smaller deepwater developments will struggle to be economically viable in the current environment. However, the larger deepwater fields, such as Brazil's presalt fields should remain attractive. BG and Petrobras reported that their presalt developments had a break-even of \$45/bbl.

Industry sentiment

The results of EMA's 2015 Floating Production Industry Survey largely fulfilled the firm's expectations, with a few exceptions. In terms of regions with the largest growth opportunities, most respondents agreed that Brazil, West Africa, and Southeast Asia would be the dominant areas. Very few were excited about the prospects for Australia, while EMA believes that there will be a few, extremely large FLNG projects there in the next five years. Perhaps the lack of enthusiasm is explained by the limited number of projects, despite the very large capex. ●

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Sevan adapts circular floaters for future regasification, FLNG needs

Nick Terdre
Contributing Editor

Sevan platform outfitted with 700-MW power plant.
(Photo courtesy Sevan Marine)

Sevan Marine is developing new applications for its cylindrical floater technology. To date, the Arendal, Norway-based contractor has designed and supplied floaters for use as FPSOs, drilling rigs and accommodation units. It delivered its first flotet to Teekay in February. More recently, its focus has been on concepts for floating storage and offloading units (FSO); gas-handling operations such as FLNG and floating storage and regasification (FSRU); and studies for power plants and carbon capture.

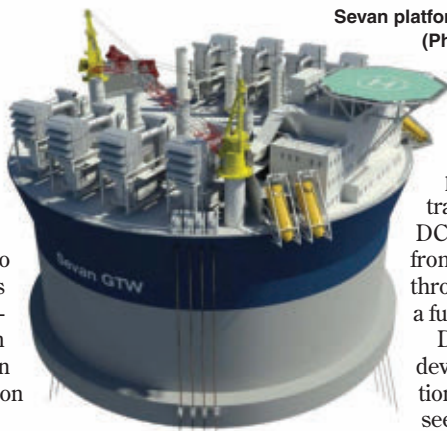
The company has now developed an offshore regasification/power generation concept intended that could meet Japan's energy needs in the post-Fukushima age, as the country seeks to switch out of nuclear power and replace it largely with imported gas and renewable energy.

Sevan delivered a presentation to Japanese utility companies in December, according to Chief Business Development Officer Fredrik Major. The proposal also met with interest in government circles – a representative of the Japanese energy ministry accompanied Major and his colleagues while they were in the country, and ministry representatives expressed their intention of promoting funding for a study of the concept.

While Japan has long been a large-scale importer of LNG, one particular advantage of floating regasification is that the operation can take place far from shore and is therefore safe from the risk of earthquakes and tsunamis, as well as being remote from inhabited areas. By adding a power plant, the need for an onshore gas terminal and electricity plant is also eliminated.

The floater that Sevan envisages for these operations is a mid-size unit, the same as its FLNG unit. Regasification requires less equipment than liquefaction, thereby freeing up space for the power plant. Sevan's process subsidiary KANFA Aragon would engineer the regasification facilities, while the company's partnership with Siemens would take care of the power generation. This would use Siemens' widely-sold SGT-800 combined-cycle industrial gas turbine.

The application would require two 350 MW blocks, each comprising five SGT-800 gas turbine generator sets, five heat recovery steam generators and one SST-



900 steam turbine generator set. Generation efficiency is close to 55%. Siemens would also be responsible for design of the power transmission facilities. Power could be transferred ashore as either high-voltage AC or DC current. Sevan foresees a four-year period from front-end engineering and design (FEED) through construction and outfitting to delivery of a fully commissioned unit.

DNV GL has also been involved in the concept development, providing safety and risk evaluations and third-party verification as well as overseeing regulatory compliance.

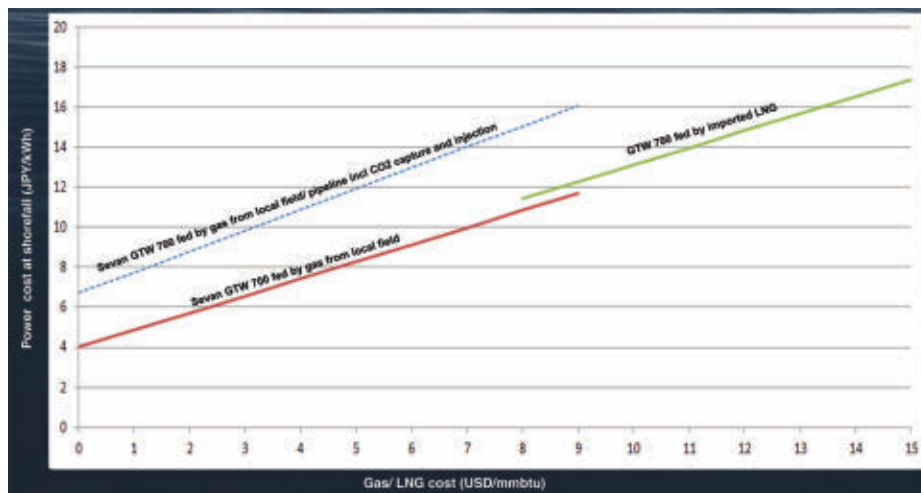
To generate 700 MW, the required gas is around 120 cf/d (3.4 cu m/d), equivalent to 5,800 cu m/d (204,825 cf/d) of LNG. The LNG storage capacity is about 200,000 cu m (7.063 MM cu ft), sufficient for some 35 days' generation.

Another potential application, also relevant to Japan, would be to use the floating power plant in combination with an offshore wind farm, acting as a swing producer to keep the amount of power supplied to shore constant in the face of fluctuating output from the wind farm. In this case the floater and the wind farm would share common transmission facilities. While LNG would be the obvious gas source in the case of Japan, elsewhere the floating power plant could be powered by gas from local sources. One example is Myanmar, which has its own gas reserves but a deficit in local energy generation.

Adjustable power

Without the need for regasification equipment, it would be possible to install a carbon capture system on the floater to work in conjunction with the power plant. The feasibility of this concept, known as Sevan's GTW 700 post-combustion carbon-dioxide (CO₂) capture

Indicative power cost for Sevan 700MW power plant at cable shortfall, assuming 600MW power production, 50 km (31-mi) HVAC connection to shore and 30-year investment depreciation at 10% Internal Rate of Return (IRR). (Table courtesy Sevan Marine)



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plant, has been established in two studies by the SINTEF research institute in Trondheim, Norway. These showed that the facilities can be easily integrated with a natural gas-fired power plant on a Sevan floating structure. The process enables up to 90% CO₂ capture, although it reduces the net efficiency of power generation to around 45%, or 570 MW. The captured CO₂ is compressed to liquid form for injection into a subsurface storage reservoir.

Other benefits of the floating power plant are that the power rating can be adjusted in 70 MW steps, and thus closely tailored to the need at any time. As with any floater, the unit is mobile and can be easily relocated. Sevan envisages that a utility or group of utilities under a company license would own the unit – as is the case of the *Goliat* FPSO in the Norwegian Barents Sea, owned by Eni, and Dana's *Western Isles* FPSO east of Shetland in UK waters.

Sevan's technology, being geostationary, does not require turret mooring, unlike conventional ship-shape floaters. The turret system that allows a ship-shape FLNG unit to weathervane is a major cost element. In the case of Shell's *Prelude* offshore northern Australia, for example, the price tag for the 100-m (328-ft) high, 12,000-metric ton (13,228-ton) turret is thought to be \$500 million or more. Moreover, importing gas through a swivel is a technically demanding and potentially hazardous operation, but this is not required in the case of the circular floater.

Sevan's operating experiences with its circular FPSOs have confirmed other inherent engineering advantages compared with ship-shape or conventional semisubmersible hulls. These, the company claims, include insignificant bending stresses; elimination of wave-induced fatigue loads; minimal hull deflections; lower pitch and roll motions; and lower heave acceleration and amplitude.

Topsides/storage arrangement

The hull of the company's FLNG design has a 106-m (348-ft) diameter and a double bottom, supporting a three-deck topsides: uppermost is the process deck, with an area of 13,000 sq m (139,931 sq ft), with a utility deck underneath, and below that the main deck. Total topsides weight is 31,500 metric tons (34,723 tons), of which 17,000 metric tons (18,739 tons) is accounted for by the gas processing and liquefaction facilities. There is storage capacity for 180-210 cu m (6,357-7,416 cu ft) of LNG in six main tanks, 20,000 cu m (706,293 cu ft) of liquid petroleum gas (LPG) in a central tank (which could also be used for LNG if LPG storage is not required); and 250,000 bbl of condensate in six smaller tanks – condensate and LPG are extracted during the pre-processing process.

The liquefaction process makes use of KANFA Aragon's patented technology which is based on the well-proven dual nitrogen expander cycle optimized for offshore application and reportedly using up to 15% less energy than similar dual expander cycles. The FLNG unit is equipped with two LNG trains, each sized to produce 1.2 MMt/yr of LNG, making a total capacity of 2.4 MMt/yr based on a gas feed of 333 MMcf/d.

The process requires a large intake of cooling water – typically 18,000 cu m/hr (635,664 cu ft/hr) for 2.4 MMt/yr. In areas with high sea water temperatures, process efficiency can be significantly improved, Sevan adds, by taking colder water from deep down through free-hanging vertical hoses. Again, as the unit is stationary, there is no interference between the hoses and the mooring or risers to prevent the deep deployment of these hoses.

There is flexibility with respect to hull fabrication, which can be performed in a drydock, on a skidway, slipway or submersible barge. The self-supporting prismatic type B SPB tanks included in the design are prefabricated, offering a choice of location, while the membrane tanks are fabricated in situ. The topsides are modularized and fabrication can therefore take place at a variety of locations.

Hull/topsides integration and topsides hook-up will normally take place in the hull fabrication yard, allowing a fully commissioned unit to be delivered and on-field hook-up reduced to a minimum. Transportation to the field location can either involve a dry tow on the back of a heavy-lift



LNG transfer from the Sevan FLNG unit using the HiLoad LNG system. (Image courtesy Sevan Marine)

vessel, in the case of a longer distance, or a wet tow, with a full crew on board if desired.

Major claims the cost of the Sevan FLNG unit would be reasonably competitive, at just under \$1 billion/MMt per year. And there are further advantages in terms of offloading of LNG to tankers. For the standard ship-shape unit, the normal method is to have the tanker moored alongside, meaning that the two vessels are in contact. In such circumstances loading operations are limited to relatively low sea states. Use of hinged loading arms for LNG transfer also

means there are restrictions on the relative motions that can be permitted.

Various methods, in contrast, are feasible with the Sevan FLNG unit, including side-by-side offloading to a conventional LNG carrier alongside the platform, or offset side-by-side, with the carrier stationed a small distance from the platform.

These would allow loading operations in sea states up to 2.5 and 3.5 m (8.2 and 11.5 ft) significant wave heights respectively. Operations in up to 4.5 m (14.7 ft) sea states would be pos-

sible through tandem offloading to carriers adapted for bow loading.

Last year, in recognition of the need for loading in higher sea states, Sevan acquired the LNG loading technology that employs the HiLoad docking system, establishing the company's HiLoad LNG for this purpose. The HiLoad unit, which is equipped with four thrusters and a DP-2 dynamic positioning system, carries the loading hose to the tanker, locking onto its side and holding it in position while loading takes place. The fixed connection means there are no relative motions between the HiLoad unit and the tanker, allowing operations to take place in sea states in excess of 4.5 m. It also means that standard LNG carriers can be used, without any modifications.

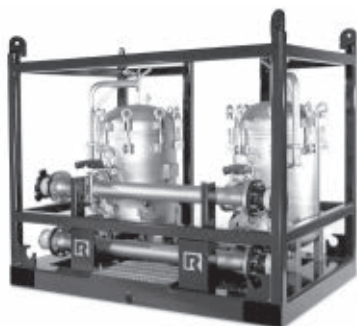
LNG is transferred through a cryogenic floating hose. Trelleborg has developed a 20-in., 20-bar (290-psi) hose for this purpose, which is currently undergoing qualification to the EN1474-II standard.

Operating costs for Sevan floaters of all types are comparatively low, the company adds, mainly because there is no turret requiring regular maintenance. Experience from the North Sea floaters indicates a need for an overall crew of about 30, a savings of roughly five compared with a conventional FPSO of equivalent capacity. The marine crew only works the day shift. ●



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Digital oilfield offers new model for production optimization

Central control rooms allow assets and data to be monitored remotely. (Photos and images courtesy Rockwell Automation)

Technology continues to evolve at a record pace, causing oil and gas producers to increasingly rely on a secure, robust communication network to support exploration, production, and wellhead operations. Transitioning to a digital oilfield is paramount for these companies to help realize and establish an effective connected enterprise and continue to drive innovation both offshore and onshore.

This transition relies on new technologies, such as mobile devices and the cloud, that already enable a myriad of other applications to connect production with enterprise systems for greater output, better use of assets, and improved decision making.

As new digital technologies are continually developed and implemented into daily operations, oil and gas companies need a way to better access, understand, and analyze the wealth of data coming from these assets. Remote-monitoring solutions can now unlock well diagnostics and other real-time data generated by countless intelligent devices.

With this increased data access, oil and gas operators can translate important asset-management information to optimize production, and reduce downtime, unplanned maintenance, well visits, and other operational costs.

Remote monitoring

Traditionally, accessing information from pumps, lifts, wellheads, and other equipment was a labor-intensive process. Onshore, workers had to drive from platform to platform and physically gather data. Offshore, one person stationed at each platform monitored performance. Field engineers made as-

Andy Weatherhead
Rockwell Automation

sumptions regarding the actual oil and gas, such as pressure, the amount being pumped, etc., at each platform. These procedures not only put people at risk, but also they were time-consuming and introduced the potential for data tainted by human error.

That is why automation providers are bridging the information gap with fully automated and integrated systems to help capture and send data from a remote site to a centralized location. Oil and gas companies can now remotely access and monitor machine data and oil and gas analytics by leveraging wireless communication and visualization solutions. As the benefits of automation, communications and information technology converge, these wireless solutions help merge disparate oilfield data into streams of actionable information, regardless of the source.

By investing in digital oilfield remote-monitoring technologies, operators can access and manage equipment, production data, and asset analytics across multiple applications from one single location, which can be hundreds or thousands of miles away from the platform itself. This technology seamlessly integrates software, hardware, and sensors to extract important operational information – such as daily oil production, energy usage, oil pressure, and more – across a variety of wellhead applications and feeds it back to a centralized location in real time. Operators can then continuously monitor

current operating conditions, troubleshoot any potential issues, and make process adjustments at an earlier stage to help increase uptime – all without leaving their workstation. They are also able to more accurately monitor their most critical asset to rationalize what is coming out of the ground, effectively allocate resources, predict changes in well data, and make assumptions based on the continuous process data variables.

Abu Dhabi Marine Operating Co. (ADMA-OPCO) was looking to increase production from its offshore operation. Many of the company's operating fields contained a large number of water-injection wells. Without access to offshore data, reservoir engineers could not properly manage the water-injection process. The company attempted several times to install wireless supervisory control and data acquisition systems, but they were unreliable and unable to deliver data from wells more than 20 km (12 mi) from the main platform.

ADMA-OPCO worked with Rockwell Automation company vMonitor to design and implement the oil company's first successful water-injection wireless remote-monitoring system. The new system tracks well pressure, temperature, and flow, and efficiently delivers the data to the main platform. This is the first wireless telemetry system for ADMA-OPCO capable of capturing data from these distant wells. The increased access to water-injection data helped the company to increase production and reduce well visits by more than 60%.

Prevent data deluge

Although remote monitoring helps optimize production, oil and gas companies must be-



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ware of information overload. As the amount of asset-related information swells, operations personnel may become overwhelmed.

To avoid information overload, operations-management solutions can be used to help convert data from across the digital oilfield platform into easy-to-comprehend information. Beyond remote monitoring, these systems gather, analyze, contextualize, and share information to help oil and gas producers optimize operations. By pairing production intelligence with intuitive dashboards and historian functionality, operations-management systems can automatically collect production data, calculate key performance indicators, and present easy-to-understand displays via wireless, remote technology.

In addition, applying operations-management solutions offers an alternative to data deluge by supporting collaborative environments where remotely located subject matter experts make decisions and trained operators apply their recommendations. Automation providers offer remote-service support to delegate data collection and analysis, troubleshooting and maintenance activities to centrally-located automation professionals. Diverting information to off-site experts can help operators focus their time on maintaining a smooth, on-site operation.

By applying working information capital across the digital oilfield, oil and gas companies can leap from simply linked operations to smart, connected enterprises. To further enhance connectivity and productivity into the future, many companies are leveraging the cloud to deploy remote-monitoring and operations-management solutions.

Cloud technology

Just as the cloud has helped revolutionize banking, telecommunications, and back office business services over the last decade, it is now helping oil and gas companies construct the digital oilfield by providing an alternative option to traditional on-prem-



Automated solutions can help alleviate the guesswork of monitoring data and performance offshore.

ise infrastructure offerings. Primarily, cloud technology eliminates the need for capital investment to design and maintain a physical data-storage infrastructure, especially for small- to medium-sized companies that do not have the budget to invest in their infrastructure.

The cloud acts as a common, secure environment to protect oil and gas systems, and can seamlessly and remotely link end-point devices across the digital oilfield – from a remote terminal unit (RTU) or offshore wellhead to a mobile device in the field – for an effective connected enterprise.

Much like cell phone users, oil and gas companies can store data from RTUs in the cloud, making the information readily available whenever and wherever it is needed. Even equipment and device configurations can be saved and backed in the cloud. For example, if an RTU fails and a new piece of equipment is required, companies will have the proper con-

figuration and application settings saved and available for immediate download.

Apart from simply storing data, the cloud also is readily scalable and supports other transformative technologies, such as mobile computing, the industrial Internet of Things, and advanced analytics. In the coming years, cloud-based systems will give oil and gas companies the expanded ability to perform analytics on the data that is already being collected, displayed, and consolidated in the digital oilfield. These companies will be able to incorporate analytics-based decision making in their processes – improving predictive maintenance, enabling improved asset utilization, and reducing risk and operations costs.

Transforming to a digital oilfield

The foundation for achieving the digital oilfield begins with planning, designing, and applying remote-monitoring and operations-management solutions. By working with an automation provider, oil and gas companies can decrease costs and risks associated with the traditional, labor-intensive, data-collection processes.

Remote-monitoring solutions help oil and gas producers visualize their operations with real-time, comprehensive data that is easily transformed into actionable information to help achieve goals of reduced downtime and increased productivity. Through cloud computing, these solutions are not only applied quicker, but also are more easily scalable as other transformative technologies emerge in the future.

By remotely tapping into the full range of production and operational data, and diverting that information to off-site experts, companies can start to realize the full potential of the digital oilfield. ●



A rendering of integrated on and offshore solutions from Rockwell Automation. The operation-management solutions depicted are used to help convert data from multiple assets across the digital oilfield into easy-to-comprehend information.

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Dual compact flotation unit delivers big gains in oil removal efficiency

Produced water treatment in half the footprint

Jeremy Beckman
Editor, Europe

The Schlumberger EPCON produced water treatment technologies group in Porsgrunn, Norway, has redesigned its compact flotation unit (CFU) technology. The resultant EPCON Dual CFU, the company claims, offers major improvements in separation and treatment of produced water on fixed and floating installations.

The original EPCON team began working on the CFU concept in the late 1990s, with the first offshore installation completed on a Norsk Hydro's Troll C platform in the Norwegian sector in 2001. According to regional sales manager Stian Johnsen, "In the North Sea we were seeing water rates increasing significantly in production wells and at the same time much stricter limits on oil-in-water discharges. We decided to respond to these changes and their potential impact on offshore operations by developing a lighter-weight, low-maintenance separation unit occupying a much smaller footprint – typically one-third of conventional technology."

The original EPCON CFU is a vertical, multi-phase (oil/gas/water) separator with no moving parts, requiring no external energy aside from supply pressure or hydrostatic head, and with a smaller volume and shorter retention time than traditional flotation units used offshore. Various processes, including gas flotation and induced centrifugal inertia forces, act in combination on the incoming fluid mixture to separate components with differing gravities. The small oil droplets agglomerate and coalesce, facilitating separation from water. Devices inside the chamber and a gas flotation effect induced by the release of residual gas from the water further aid the separation process significantly. Separated oil and gas is removed continually via an outlet reject pipe.

In 2006, M-I SWACO, part-owned by Schlumberger at the time, acquired EPCON and merged the company with UK-based hydrocy-



Images courtesy EPCON

The optimized internal design of the EPCON Dual CFU features a second oil removal section within the vessel and a second outlet for separated oil. The result, Schlumberger claims, is improved oil removal efficiency in half the footprint of conventional technologies.

clone/sand system specialist Cyclotech with a view to bidding for a broader range of process packages. Four years later, M-I SWACO was itself fully acquired by Schlumberger. Today, EPCON has CFUs operating offshore in the UK and Norwegian North Sea, Africa, Australia, Canada and China, and onshore in the Middle East and Russia.

Performance goals

"Two years ago," said Johnsen, "we decided to remodel the system to obtain a higher performance but using the same footprint. Most of the separation was being performed in the vertical medium's upper part, and we felt sure that we could make better use of the lower section. We examined the velocity profile of the gas bubbles with different internal designs, and following extensive CFD simulations and tests we ended up with the most optimal internal design."

"We built a laboratory-scale pilot at our facilities in Porsgrunn, using synthesized produced water with crude oil and saturated with gas, subjected to pressure drops." The first offshore prototype then underwent a field trial on a produced water stream in the Nor-

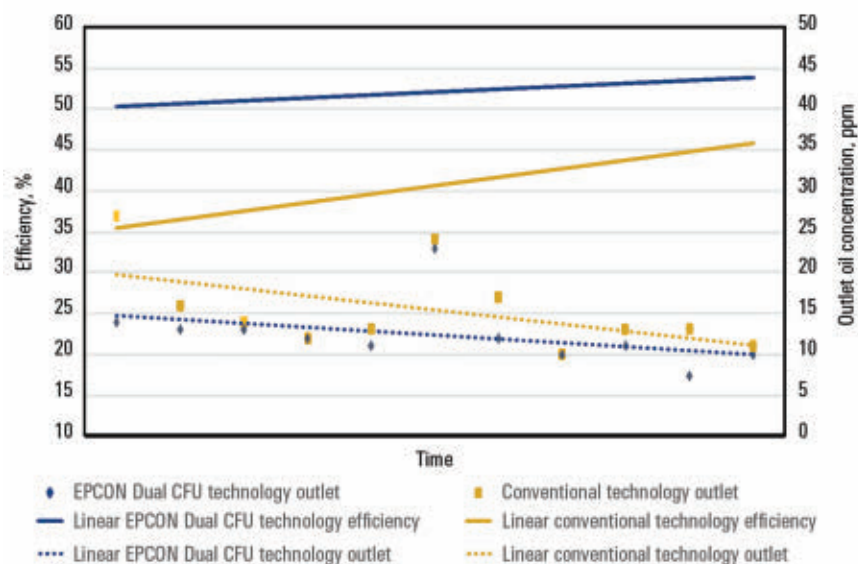
wegian North Sea in cooperation with Statoil.

"The existing installation delivered very clean water that was within the permissible overboard limits. But we still achieved a 27% improvement in oil removal efficiency, comparing the EPCON Dual unit with our traditional EPCON CFU in parallel operation."

We got the results that we expected from both the CFD simulations and lab benchmark tests in terms of oil removal efficiency and the behavior of the bubbles, and the number of bubbles that reached the center of the lower part of the vessel."

Johnsen continued, "Basically, what we have done is to combine two separation units into one. Other multi-stage units merely repeat the same process over and over again, whereas in our redesigned system there are two different processes going on in the upper and lower part of the vessel. We now take advantage of what was previously 'lost' gas to recover more oil from the water. In our EPCON Dual, this last stage capturing of the 'lost' bubbles is also different compared to other technologies – the gas flow pattern is co-current with the liquid flow."

In addition, the combination of the gas-



Actual oil-in-water measurements compared with separation efficiency for the EPCON Dual CFU (blue) and for conventional technology (yellow). The EPCON Dual CFU delivered 27% improved efficiency throughout a field trial on a North Sea installation, including at low-inlet oil-in-water values.

stripping effect and optimized reduction in dispersed oil through use of nitrogen as flotation gas can lower polycyclic aromatic hydrocarbon emissions by up to 83%, the company

claims. Alkylated phenols and benzene, toluene, ethylbenzene, and xylene compounds can be reduced by up to 88%.

Offshore gas/condensate streams tend

to be low in salinity. In certain applications, it may be necessary to add some salinity to the water, Johnsen said. For other applications where there is limited availability of process gas on the platform, nitrogen can be applied as an alternative medium. "However, you must be careful about the composition of the chemistry that you use and where you choose to inject it into the liquids/gas stream. If the field's production profile changes over time, you want to avoid creating shear forces."

As with the traditional EPCON CFUs, the EPCON Dual CFU can be delivered with design capacities for produced water ranging from 6 to more than 1,200 cu m/hr. The EPCON Dual CFU system, too, is designed typically for a 20-year lifespan and can be manufactured from different materials.

Depending on the operating environment and requirements, systems can be customized. Internally-lined low-temperature carbon steel versions of the systems typically have faster delivery times. In demanding environments and process conditions, higher grade alloy systems such as duplex or super-duplex stainless steels and titanium would commonly be used. Standard pressure vessel designs accommodate most pressure, temperature, and design codes. ●



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Subsea processing moves forward with challenges in tow

Jon Fredrik Müller
Rystad Energy

Offshore developments are continually moving into deeper waters and the nature of the game is that the biggest potential targets get drilled first with the most commercial fields being developed. As the offshore fields mature, pressure differentials narrow and step outs from existing infrastructure increase with the newest technology being developed to tackle the challenges.

New technology has been implemented gradually both in greenfield developments and modifications of existing fields, but for many of the technologies that adaptation is still low. There are several key subsea technology developments in the works that could reduce future barriers for widespread use.

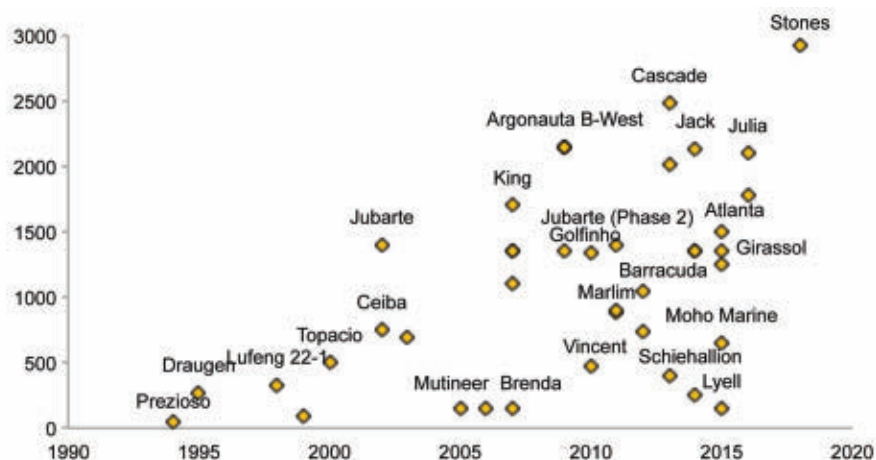
Subsea processing is the concept of gradually moving the entire topsides processing facilities to the seabed which would create better financial returns due to increased recovery. In some cases, subsea processing is a prerequisite for making marginal field developments economically viable. By moving the processing of the well flow from the topsides to the seabed, projects previously deemed non-commercial may become economically viable, while increasing the recovery rates on existing fields. Currently, Petrobras, Statoil and the majors, along with equipment manufacturers, are driving the developments behind subsea processing. While subsea processing encompasses a large array of technologies and systems, there are mainly four technologies that have been implemented by the industry so far: boosting, separation, water injection, and compression.

Subsea boosting

Subsea boosting is the application of subsea pumps to "boost" the pressure in the well stream. The main advantages of subsea boosting are accelerated production; increased production and recovery; development of low energy reservoirs; heavy oil fields; long tiebacks; and where pressure differentials pose a problem.

The first subsea booster pump was a twin-screw multi-phase pump developed by GE Oil & Gas, which was installed in Eni's Prezioso field in Italy in 1994. Since this first installation in water depths of 164 ft (50 m), the technology has reached deeper depths. For instance, the Cascade oil field in the Gulf of Mexico (GoM) is currently the deepest subsea boosting system installed, at a water

Subsea boosting projects by water depth (meters) and installation year.



(Graphs courtesy Rystad Energy)

depth close to 8,202 ft (2,500 m); and Shell is currently contemplating booster pumps at its Stones development in 9,514 ft (2,900 m). Although GE was first, it is OneSubsea (through Framo Engineering) that has become the market leader, capturing most of the market with their helico-axial pumps. Today, the booster technology is by far the most mature of the subsea processing technologies.

Booster pumps are mainly used in oil fields with low gas to oil ratios, both for heavier and lighter crudes. The key regions have been, and will continue to be, Brazil, the US Gulf of Mexico, the North Sea, and West Africa due to the water depths, reservoir characteristics and tieback distances.

Subsea separation

Subsea separation is the concept of separating gas/liquids or oil/water at the seabed. Such systems bring solutions to flow assurance challenges such as hydrates and slugging; enables viability of challenging reservoirs; prolongs economic lifetime of fields; debottlenecks flowlines, risers and topsides; and handles water and sand at the seabed, thereby reducing the potential costs associated with a topsides facility. Many of the installations have been in conjunction with booster pumps with subsea separation today, being a proven technology. While OneSubsea has taken the lion's share of the booster market, it is FMC Technologies

that have become the market leader in the separation segment, being system provider for the majority of projects completed.

While experimentation on subsea separation systems occurred prior to the 2000s (Zakum 1965, Highlander 1985 and Argyll 1986), most people regard the Statoil Troll C pilot on water separation and injection in 2001 as the first modern subsea separation unit. The Troll system was installed in 1,115 ft (340 m) of water depth, 2 mi (3.5 km) from the platform. Today, it is Shell's Perdido field which is the deepest application of subsea separation at approximately 8,202 ft (2,500 m). Subsea separation systems have now been installed at 11 fields operated by Petrobras, Statoil, Shell, and Total. All the fields lay in Brazil, Norway, US GoM or Angola, and going forward, these areas, including the rest of the North Sea and West Africa, is seen as the primary markets for such systems.

Water injection

Subsea water injection is used to increase recovery, and thus, important for value creation. In conventional injection systems, water is normally required with the water treatment being performed topside. High pressure water pipelines to the wells are installed, which means higher development costs. With subsea water injection, the whole system is placed on the seafloor, only requiring power from the shore/host.

The main potential advantages of subsea

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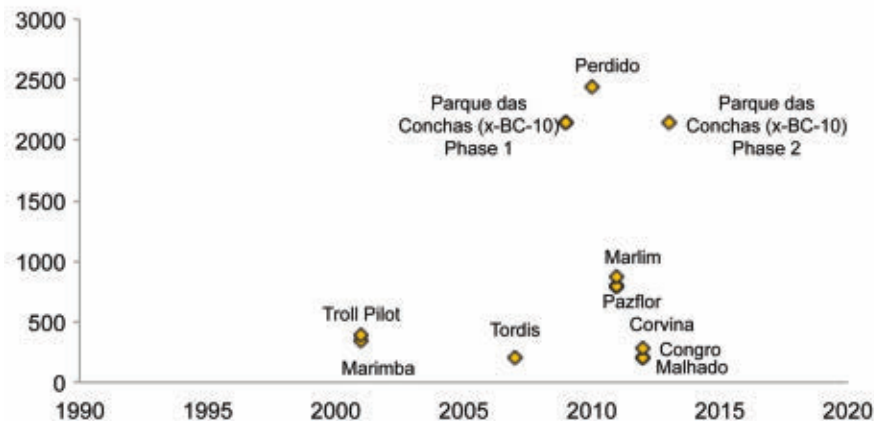
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Subsea separation projects by water depth (meters) and installation year.



water injection include the ability to avoid expensive high-pressure flowlines, potentially expensive topsides modifications, and enabling more flexible development solutions in terms of injection well placement and timing. The first system was installed at Columbia E in the UK part of the North Sea in 2007. Since then, similar systems have been installed on the Tyrihans field in Norway (2011) and at Albacora L'Este in Brazil (2013). However, costs remain high and need to decrease to see more widespread use of these systems.

Subsea compression

Subsea compression increases the pressure difference driving the gas through the flowline, and it effectively lowers the wellhead pressure, thus speeding up production and increasing recoverable reserves. The compressor can be placed close to the well, which increases and accelerates the production. Until recently, the solution has been to install gas compressors on an existing platform, or to build a new staffed compression platform. By taking the compression subsea, one can reduce the need for additional platforms. However, subsea compression systems are complex and require large gas resources to justify the investments.

Subsea compression is a technology under development and remains to be proven, although Statoil has qualified two different systems, Asgard and Gullfaks Compression, which will be installed in the near future. In addition, the technology has been tested in an onshore pool on the Ormen Lange Pilot project, where Shell is the operator. However, in April 2014, Shell put the concept selection for Ormen Lange on hold, citing too high costs, and an option value in compression not being time critical. While the Ormen Lange and Asgard fields will require separation of liquid from the well stream before compression, Gullfaks South will involve compression of wet gas without pre-separation. Aker Solutions is working on the Asgard project, and they also

had the Ormen Lange pilot, while OneSubsea recently delivered the system for Gullfaks South.

With the subsea processing technology moving forward, the number of platforms may be reduced in the future. Even with a full-fledged subsea factory, the distance to shore might be such that offshore export solutions are preferred and risers will still be needed.

Water pressure and the structural integrity of the risers have been an issue that flex pipe manufacturers have been working on for many years. By the end of the 2000s, flexible production risers were approved down to around 6,562 ft (2,000 m), however, there were rigid and hybrid solutions (riser towers/submerged bouys) capable of handling deeper waters. Currently, there are flexible production risers capable of withstanding 8,202 ft (2,500 m), and the qualification of equipment for deeper waters is likely to continue. Into the 2020s we might see water depths at around 9,843 ft (3,000 m), for example with the giant Libra development moving forward in Brazil. These depths are at the limits of what is possible today, but the hope is that emerging composite flexibles (more strength and less weight) will be qualified to handle water depths beyond 9,843 ft (3,000 m).

What does the future hold for subsea processing? Statoil is working on completing the subsea factory by 2020. Several of the building blocks needed are in place, however, this vision needs to be fine tuned to reach such an aggressive target. With the current downturn in the market, the mid- to late-2020s is probably a more realistic target before such a complete subsea facility is tested and in place. There are several challenges toward the full-fledged subsea factory.

Some of the obstacles needed to overcome are:

Power distribution. Large subsea fields with high power inputs, many components and long step-out distances means that subsea variable

speed drives will be needed to convert, distribute and control the electricity. The subsea components run on high voltage alternated current, which has limits on transmission distance relative to power, meaning that high voltage direct current may be needed. Major electro and automation companies like ABB and Siemens are working on these aspects.

Control systems. Putting all the equipment subsea also increases the requirements for the control systems. There will be a need for increased bandwidth, real-time information on system performance, in addition to increased demands on safety functionality and regularity.

Oil storage. Not seen as a major technological challenge by the operators, but a component that needs to be tested and qualified. Kongsberg Oil & Gas has an ongoing development project for Statoil.

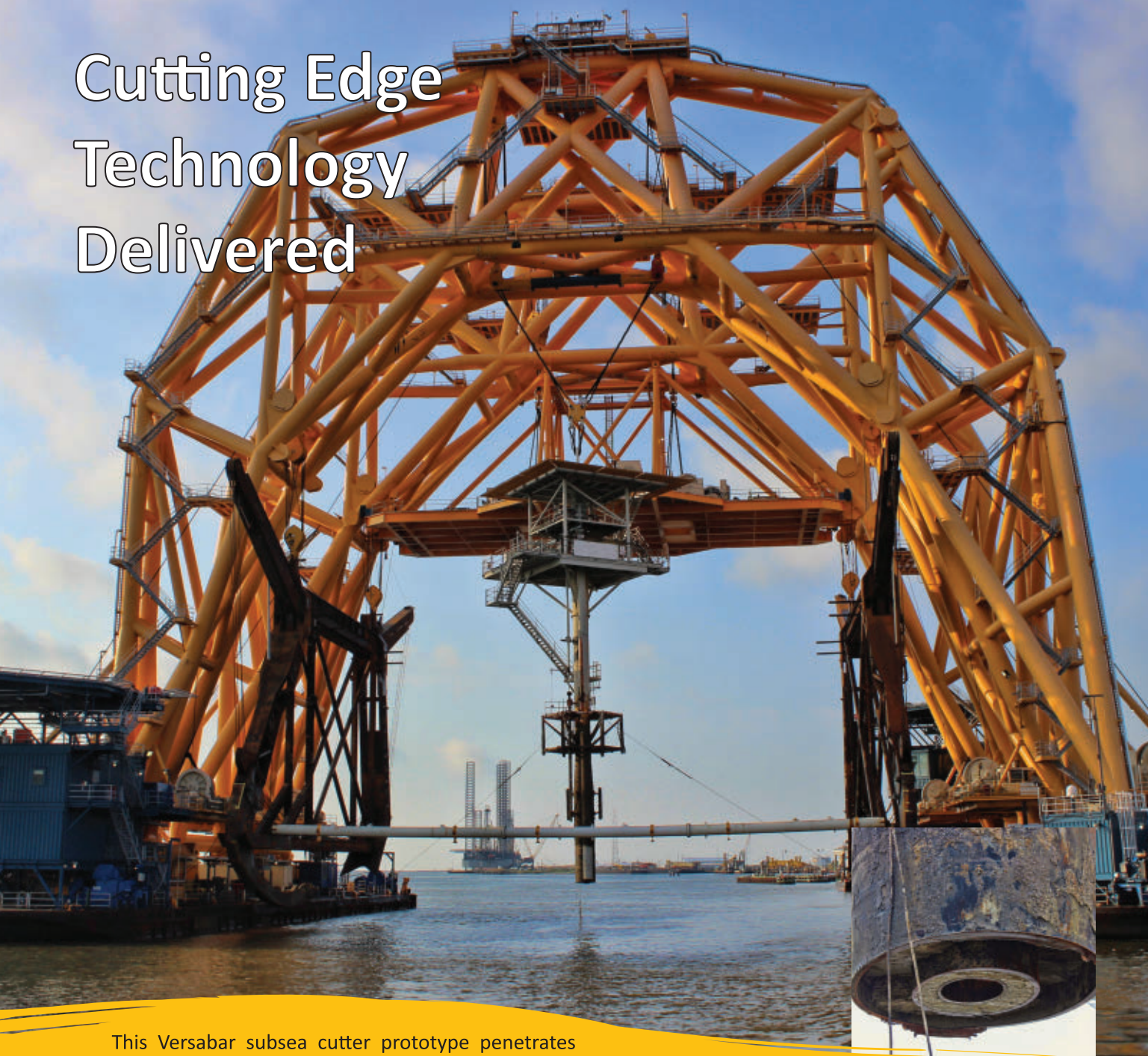
Monitoring. Knowing the state of the well stream will be crucial in terms of production monitoring and flow assurance. Improved reliability for subsea and multi-phase sensors will be key.

Subsea well intervention. Subsea processing fields bring challenges related to year-round well intervention and maintenance operations from ships in high waves, particularly the handling of large and heavy processing modules. The reduced accessibility of a subsea installation, compared to a topsides, brings additional requirements to the system uptime, maintenance on demand and a general optimization of the intervention frequencies. To handle the up to 400-ton modules at Asgard, in waves of 15 ft (4.5 m), Technip is supplying Statoil with a new handling system to lower and raise modules over the side of the vessel.

Integration, reliability, and cost. Enabling and qualifying the integration, i.e. cooperation between all of the components, is a key challenge with standardization being a key topic. In addition, equipment needs to be more robust, have a proven high-reliability and a decrease in cost.

Considering the number of subsea fields (~1,500) compared to the number of subsea processing projects (boosting ~30; separation ~15; compression ~three), the current technology adoption is low. The main reasons for this are related to costs; uncertainty regarding reliability (proven on boosting and separation by now); and a general conservatism in the industry. These factors are likely to be spurred by the current cost-sensitive environment where low-risk solutions seem to be preferred. This downturn in the market might be a bump in the road in terms of realizing the subsea factory. However, looking toward the end of this decade and into the 2020s, offshore field developments are forecasted to be one of the most important sources for new liquids production. With shelf production maturing, and the most prospective areas in deeper depths, the need for these technologies will increase. ●

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Offshore industry examines integrity of CO₂ pipelines

Push to unlock stranded gas expected to spur future systems

**Jock Brown
Sigbjørn Rønneid
Mohammad Ahmad
Angunn Engebø**
DNV GL – Oil and Gas

With energy security and climate change at the top of the global agenda, climate change mitigation technologies such as carbon capture, utilization and storage (CCUS) are gaining momentum. The number of offshore CO₂ pipelines is therefore expected to grow significantly in the future.

CCUS technology offers a solution for both supporting production of incremental hydrocarbon reserves from existing fields while at the same time storing CO₂ away from the atmosphere, avoiding climate impacts. As fossil-based fuels continue to be part of the energy mix in the foreseeable future, CCUS will be critical, particularly for reducing emissions from coal-fired power plants. The push to unlock high CO₂ stranded gas fields is also likely to spur the development of CO₂ pipeline technology offshore.

In Europe, Brazil and Southeast Asia, the most advanced CO₂ storage sites are offshore. The demand for such facilities is driving the need for reliable transportation pipelines from onshore sources to offshore storage sites. The public acceptance issue for onshore storage is another driver for the offshore storage business. As well as the clear advantage to the environment, the injection of CO₂ in offshore oil and gas res-

ervoirs could extend the lifetime of the well through enhanced oil recovery (EOR).

Opportunities for the offshore storage of CO₂ are prevalent in the North Sea with projects underway off the UK and Norway. There are also opportunities in offshore Brazil and China. Regarding sour gas developments and the trend of increasing use of LNG in Southeast Asia, there is an expectation that more of these “stranded” gas fields will be developed.

Transferrable technology

Transportation of CO₂ is generally considered the easier part of CCUS, since the pipeline sector is well established and the technology is well known. However, closing existing knowledge gaps associated with the flow dynamics and assurance of CO₂ pipeline transport has the potential to reduce uncertainty and avoid unnecessary high safety margins.

The technology for conveying CO₂ is typi-

cally the same as that for any other gas and liquid pipelines offshore. From the outside, it would be difficult to tell the difference between a CO₂ pipeline and a natural gas pipeline. The key differences can be found on the inside.

The thermodynamic and corrosive properties of pure CO₂ are different from those of other fluids, such as natural gas, conveyed in pipelines. The presence of impurities in the CO₂ stream, like those from anthropogenic sources, adds another level of complexity. Understanding how CO₂ disperses into the atmosphere during planned, as well as accidental release scenarios is essential for pipeline route planning and risk assessment of pipeline design. This understanding can be used to demonstrate the effect on pipeline design and is essential to construct cost-effective and safe offshore CO₂ pipeline solutions.

Research around the world is building on enhancing the understanding of the sci-



Joint industry projects are playing a major role in the research effort towards CO₂ pipelines, with DNV GL-led JIPs such as COSHER and CO2PIPETRANS working to fill many of the knowledge gaps. (Photos courtesy DNV GL)

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A new joint industry project, "CO₂ Subsea Releases – Small Scale Experimental Programme," will explore CO₂ subsea releases under different conditions of leak size, pressure, water depths and direction of the release.

ence and fundamental properties of CO₂, in particular the thermodynamic and corrosive properties. The main body of work currently being undertaken builds on the experiences of operating pipelines carrying pure natural CO₂ for the EOR industry in North America.

Collaborative research

Joint industry projects (JIPs) are playing a major role in the research effort toward CO₂ pipelines. DNV GL-led JIPs such as COSHER and CO₂PIPETRANS have filled many of the knowledge gaps associated with CO₂ pipeline transport.

Results from the CO₂PIPETRANS project, which involved 15 JIP partner organizations, focused on the implications of the thermodynamic and corrosive properties in a CO₂ pipeline. The project investigated the dense phase CO₂ release model validation data, fracture arrest and corrosion on the transportation component of CCUS projects with the aim of updating recommended practice, DNV RP-J202 for the design and operation of CO₂ pipelines.

Computer simulations of dispersion were used to assess the potential consequences of an accidental release from a pipeline. Previously, CO₂ pipelines have been designed using unverified computer simulations, due to the lack of experimental data. Data made available by CO₂PIPETRANS can be used to validate computer simulations used in CO₂ pipeline design, thus optimizing the design process.

The important technical and financial contributions of such collaborative initiatives illustrate the importance the industry has placed on the issue. This wealth of knowl-

edge has led to the initiation of another JIP to undertake experiments releasing CO₂ through a water column to understand its dispersion and dissolution. The "CO₂ Subsea Releases – Small Scale Experimental Programme" currently involves several major operators including National Grid, Eni, and Petrobras, and more participants are welcome to join the project.

The JIP will explore CO₂ subsea releases by generating data from well-defined experiments under different conditions of leak size, pressure, water depths, and direction of the release. Simulation of punctures, as well as ruptures, will be carried out at DNV GL's world-class Spadeadam Test Site. State-of-the-art computational fluid dynamics (CFD) models will be employed to investigate the applicability and accuracy of current modeling techniques against the recorded experimental data. The purpose of this is to identify opportunities for modeling improvement and to provide guidance for modelers undertaking leak consequence assessments.

The DNV GL Recommended Practice "DNV-RP-J202 Design and Operation of CO₂ Pipelines" will be updated to reflect the new knowledge and help ensure that the highest safety standards are met when transporting CO₂. This RP is one of a number of widely-adopted industry guidelines developed by DNV GL for CO₂ handling, such as Recommended Practices for CO₂ Capture, CO₂ Pipelines and CO₂ Geological Storage.

Standards and recommended practices

The subject of CO₂ transportation by pipeline is of widespread and increasing impor-

tance as many governments and communities worldwide come to terms with the issues of carbon capture and storage for the mitigation of climate change. The transportation aspect is often looked upon as the "missing link" in a concept that is already being widely embraced.

DNV GL has created a series of internationally recognized standards and recommended practices together with the pipeline industry. Since 1976, DNV GL has issued a number of pipeline codes, comprising service specifications, standards, and recommended practices that are currently widely used by the industry.

The key challenge for CCS and the transportation of CO₂ are the ongoing international negotiations and debates for a firm and unified agreement on climate change. The likelihood of this happening in the near future remains uncertain, and this in turn has made many industry players reluctant to commit significant budgets to solving many of the outstanding issues. However, this does not mean that innovation and technology development is standing still. R&D work continues to examine solutions that will optimize design, reduce costs, and continue efforts to build pipeline infrastructure. ●

The authors

Jock Brown is the project manager for the CO₂PIPETRANS JIP and is a senior consultant in Carbon Capture, Utilisation and Storage with DNV GL based in Oslo, Norway. He holds a masters of engineering in chemical engineering from Canterbury University in New Zealand.



Sighjorn Røneid is a senior pipeline engineer based in Oslo, Norway, and is leading the fracture arrest work package testing in Norway and Italy, and is responsible for the update of RP-J202. He holds a master of science in naval architecture and marine engineering from NTNU in Norway.



Mohammad Ahmad is the project manager for the COSHER and Sub-CO₂ JIPs on CO₂ pipelines. Ahmad is a thermohydraulics specialist. He holds Phd and master of thermal and mechanical engineering from INPG in France and an MBA from Imperial College London in the UK.



Angunn Engebø is a principal consultant in Safety and Carbon Capture, Utilisation and Storage with DNV GL based in Oslo, Norway. She holds a master of science in chemical engineering from The Norwegian Institute of Science and Technology.



Deepwater Horizon Oil Spill

Economic and Property Damages Settlement

The Deadline to file a Claim is June 8, 2015

June 8, 2015 has been established as the deadline to submit a claim in the Economic and Property Damages (“E&PD”) Settlement with BP Exploration & Production Inc. and BP America Production Company (“BP”) related to the Deepwater Horizon Oil Spill. So if you are eligible to file a claim, you must act soon.

WHO IS INCLUDED?

The E&PD Settlement Class includes people, businesses, other entities, and properties in the states of Louisiana, Alabama and Mississippi, and certain counties in Texas and Florida, that were harmed by the Deepwater Horizon oil spill that occurred on April 20, 2010. The website DeepwaterHorizonSettlements.com has detailed descriptions and maps of the included geographic locations to help you determine whether you are a part of the E&PD Settlement Class. Additionally, you can call 1-866-992-6174 or e-mail questions@DeepwaterHorizonEconomicSettlement.com to find out if a geographic location is included.

WHAT ARE THE PAYMENT CATEGORIES?

The settlement provides payments if you had economic loss or property damage because of the Deepwater Horizon oil spill. By submitting a claim, you can request a payment in one or more of the following seven categories:

- Economic Damage ■ Loss of Subsistence
 - Vessel Physical Damage
 - Real Property Sales Damage
- Vessels of Opportunity Charter Payment
 - Coastal Real Property Damage
 - Wetlands Real Property Damage

Economic Damage payments are available for Individuals and Entities that lost profits or earnings as a result of the Deepwater Horizon Incident. **Coastal Real Property** payments are available for property that was physically damaged in connection with the Deepwater Horizon Incident. Detailed descriptions of all seven categories are available at the website.

There is no limit on the total dollar amount of the E&PD Settlement. All qualified and timely claims will be paid in full once they are approved. The Settlement also allowed for Seafood Compensation claims, but the deadline for those claims has passed.

HOW DO I REQUEST A PAYMENT?

You must submit a Claim Form to request a payment. You can get a copy of the various Claim Forms by visiting the website or by calling 1-866-992-6174. Claims can be submitted online or by mail. If you have questions about how to file your claim, you should call the toll-free number for assistance. The claims process can be complex, so if you are eligible to file a claim, you should act now so you may complete your claim before the **June 8, 2015** deadline.

DeepwaterHorizonSettlements.com ■ 1-866-992-6174

People

Steven Newman has resigned as president, CEO, and a director of Transocean Ltd. Until a permanent replacement is named, **Ian Strachan**, chairman of the company's board, will also serve as interim CEO.

Wood Group Mustang has appointed **Michelle McNichol** as CEO. She succeeds **Steve Knowles**, who has retired from the company.

Oceaneering International has named **Roderick A. Larson** as president and COO.

Wood Group PSN has appointed **Dave Stewart** as CEO.

Dave Baker has joined INTECSEA as director of its UK operations.

Garth Johnson, CEO and director of TAG Oil Ltd., and **Drew Cadenehead**, COO, have submitted their resignations.

Cameron has elected **Brent J. Smolik** and **R. Scott Rowe** to its board of directors.

Tesla Offshore has promoted **Matt Keith** to vice president and geoscience manager.

Vladimir Krokha has been named director general of Gazprom Dobycha Shelf Yuzhno-Sakhalinsk.

Topaz Energy and Marine has appointed **Jay Daga** as CFO. COO **Roy Donaldson** has left the company. **Geoff Taylor** will act as interim COO until a successor is named.

Andy Goldsmith has joined the International Marine Contractors Association as technical adviser marine, with particular responsibilities for dynamic positioning.

Karyn F. Ovelmen has stepped down as executive vice president and CFO of LyondellBasell.

Penspen has named **Walt Doxford** as head of integrity for Europe and Africa.

Energy Ventures has appointed **Ian Norbury** as acting CEO.

ES Platform Holdings has appointed **Mark Reese** as chairman of the board of directors.

Douglas Sedge has joined Fotech's board of directors as chairman.

Ulstein Design & Solutions has hired **Bernt-Aage Ulstein** as design manager and **Frode Sollid** as innovation and development manager.

Michael Taff has resigned as senior vice president and CFO of Flowserve Corp.

Interwell UK has appointed **David Aitken** as managing director. He succeeds **Andrew Loudon**.

Anadarko Petroleum Corp. has elected **Mark C. McKinley** as an independent director of the company. He also was appointed a member of the board's Audit Committee.

ACE Winches has appointed **Colin Black** as chief commercial officer.

Simon Thompson has resigned from the Amec Foster Wheeler board of directors. **J. Kent Masters** has joined the board as a non-executive director.

2H Offshore, an Acteon company, has appointed **Phil Ward** as a director in its Aberdeen office.

Bill Herron has joined STATS Group as group technical director and will be responsible for its product development, standardization, and project design requirements for UK, European, Middle East and Far East markets. **Doug Krokosz** has joined the company as technical director for the USA and Canada.

Charles Czajkowski has joined Tracerco as business manager, and **Sarika Pugla** has joined as reservoir technology manager.

Songa Offshore SE has elected **Johan Kr Mikkelsen** to the board of directors. **Jon Bjørstad** has resigned from his position as director of the company.

Exova has appointed **Campbell Ure** as general manager of its Edinburgh and new Aberdeen laboratories.

Richard Jenkins has joined CLS Offshore as delivery director.

MMT has appointed **Audun Brandtzaeg** as managing director for MMT Norway.

LUX Assure has appointed **Melanie Reid** as its product line manager for its chemical monitoring technology, CoMic.

Mark G. Papa has resigned from EOG Resources' board of directors.

Det norske oljeselskap ASA has appointed **Olav Henriksen** as senior vice president of projects.

Ashtead Technology has hired **Kevin Murray-Taylor** as global product sales manager.

Chris Bruijnzeels, senior vice president development of Lundin Petroleum, has stepped down.

FAR Ltd. has appointed **Gordon Ramsay** as executive general manager, business development.

Bureau Veritas has appointed **Paillette Palaiologou** as marine marketing and sales director within the Marine & Offshore Operating Group.

Swire Oilfield Services has appointed

Wayne Manning as chief business development officer and **Dag Rune Gabrielsen** as HR director.

GAC UK has appointed **Adrian Henry** as offshore manager for the UK and **Michael Henderson** as branch manager of GAC Aberdeen.

The Sparrows Group has promoted **Mark Beveridge** to European operations director and has recruited **Martin Thomson** as head of business acquisition and strategic development for Europe and Africa.

Camcon Oil has appointed **Abdel Ben Amara** as business development manager for the Middle East and North Africa.

Mirage Machines, an Acteon company, has appointed **Adam Polisen** as general manager.

David Mair has joined Ferguson Group as group sales and business development director.

London Offshore Consultants has appointed **Andrew Pointing** to group director, Marine Assurance and Risk. The company has named **Alan Clifton** as managing director of LOC Norway.

Rajesh Salem has joined RigNet Inc. as vice president, strategy and marketing.

Elite Control Systems has named **James Eadie** as field sales engineer.

Greene's Energy Group has promoted **Tracy Cummins** to vice president of key account management.

Vikoma International has appointed **Paul Rayner** as sales director.

Suretank has hired **Abby Carragher** as area sales manager for the Netherlands and Denmark.

Lou Dennis has been named general manager of MacArtney Southeast Operations.

Deep Blue Engineering UK Ltd. has appointed **Dieter Wattle** as design engineer.

Wellsite Rental Services LLC has appointed **Stephen Sheppard** as engineering manager.

Faure Herman has appointed **Douglas Gray** as regional sales manager for offshore applications.

Steve Piotraczk has joined Industrial Scientific as vice president of Americas Sales.



Keith



Krokha



Goldsmith



Reese



Ure



Amara



Cummins



Dennis



Sheppard

Company News

For the fifth consecutive year, **Enso plc** has earned first place for total customer satisfaction in the Oilfield Products & Services Customer Satisfaction Survey, which was conducted by EnergyPoint Research. Enso led all offshore drilling contractors in the survey by receiving top honors in 10 of 16 categories including total customer satisfaction; health, safety and environment; technology; deepwater drilling; harsh climate applications; shelf wells; horizontal and directional wells; and special applications. The company also rated first in the North Sea, Latin America, and Mexico.

Talisman Energy Inc. shareholders have approved the proposed arrangement under which **Repsol S.A.** will acquire all of the outstanding shares of Talisman. The completion of the acquisition remains subject to the granting of a final order by the Court of Queen's Bench of Alberta, the receipt of required regulatory approvals, and the satisfaction or waiver of other customary closing conditions. The completion of the transaction is expected in 2Q 2015.

OEG Offshore has acquired **Oilfield & Resource Rentals** and **Offshore Cryogenic Services**, both in Perth, Australia.

Element Materials Technology has opened a new materials testing and failure analysis facility in Hengelo, the Netherlands.

Penspen has opened its new Newcastle office to support its asset integrity division.

BMT Asia Pacific has opened its first-ever environmental testing facility in Jakarta, Indonesia. Certified to ISO17025 by Komite Akreditasi Nasional, Indonesia's national accreditation body, the new laboratory will provide technical testing services including noise, ambient air quality, water quality, toxicity, and emissions.

Aqualis ASA has decided to merge the operations of **Tristein AS** into **Aqualis Offshore AS**, the group's main Norwegian operational unit.

Intertek has expanded its corrosion testing services facility in Manchester, UK, with a £1.2-million (\$1.84-million) investment. Now covering 27,000 sq ft (2,508 sq m) the site has bespoke test rigs to simulate specific environments and issues. The recent upgrade enabled a pilot plant-scale flow loop and full pipe section subsea simulation studies.

Shell Canada Energy has contracted **HNZ Group** to provide offshore personnel and cargo transportation, medical evacuation services, and search and rescue flights from Halifax, Nova Scotia. The contract will use two leased Sikorsky S-92 aircraft for offshore personnel, cargo and medevac transport, and a third leased Sikorsky S-92 for dedicated search and rescue operations.

ASD Global has joined **Intergraph's** SmartPlant Alliance as an alliance technology partner, interfacing ASD's software with Intergraph Smart 3D. ASD Global will develop interfaces between Smart 3D and all its engineering automation software products, including OptiPlant, Pipe Router, and Pipe Support Optimizer.

Vallourec Canada Inc. has announced plans to expand the capacity of its Newfoundland facility.

Kongsberg Maritime has purchased about 5.2 acres for the construction of an 82,980-sq ft (7,710-sq m) office and training facility in St. Rose, Louisiana. Construction is scheduled to begin this spring. The three-story Class A building will be built on about 3 acres; the remaining acreage will be reserved for future expansion. The facility will include a 3,800-sq ft (353-sq m) training center, office space, a project department including a lab for factory acceptance testing, and a large lab area for internal training.

Subsurface consultancy **Aker Geo** has been renamed **First Geo**.

DNV GL has opened a new office in Nanjing, China.

Deep Casing Tools has established a new regional base in the Jebel Ali Free Zone area in the United Arab Emirates.

San Leon Energy has completed the sale of **Island Oil & Gas** to **Ardilaun Energy**.

Acteon has announced the start-up of **Clarus Subsea Integrity Inc.**, a new group company created from **2H Offshore's** subsea integ-

riety business segment. Based in Houston, the company's service offerings will include data management, risk based integrity assessment, anomaly management, fitness for service, subsea condition monitoring, key performance indicators, and corrosion analysis.

AVEVA has opened a new office in the Kingdom of Saudi Arabia. It will offer sales and support for all of the company's solutions and services, with particular focus on owner operators, and engineering, procurement, and construction contractors.

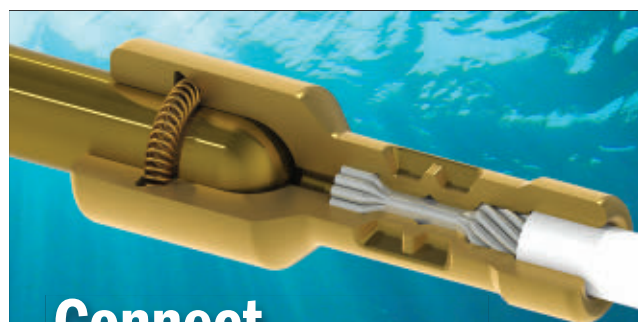
Wintershall Noordzee has renewed its offshore contract/hygiene services contract with **ESS Support Services Worldwide** by three more years.

QIC Inc. has established new offices in Kuala Lumpur and Labuan, Malaysia. The company will initially focus on providing QA/QC inspections on drilling and completion equipment. It plans to increase its Asia/Pacific presence congruent to upstream activity in the region and expects to double its operation by the end of 2016.

Royal IHC has acquired a majority stake in **Brastec Technologies**.

The MacArtney Underwater Technology Group has opened its fifth dedicated business unit in North America. Located in Jupiter, Florida, **MacArtney Southeast Operations** will cover a six-state area including Tennessee, North Carolina, South Carolina, Alabama, Georgia, and Florida.

New Industries Inc. has delivered two laboratories and two operational modules to **CSA Ocean Sciences Inc.** The mobile laboratories, outfitted with oil spill water monitoring equipment, instrumentation, and supplies, are designed to minimize response time for marine environmental operations and enable rapid mobilization to an oil spill incident.



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ROVOP, an independent provider of subsea remotely operated vehicle (ROV) services, is now hiring.



Following a contract win, ROVOP is looking for candidates to work on a construction project in the US Gulf of Mexico OCS for 5 weeks commencing in August 2015.

All the positions detailed opposite require competency certification to IMCA standard or higher for each level. Applicants should have experience with FMC Schilling Robotics UHD Gen III ROVs and deep sea electric PLC operated, active heave controlled Ennsb ROV launch and recovery systems. All candidates should also demonstrate extensive ROV operational experience on heavy construction and deep sea pipe lay vessels.

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ROVOP is committed to providing the most advanced ROV systems, exceptional customer service and the most skilled and competent personnel to its clients. If you believe you have the experience and personal attributes to match this, there are vacancies in the following positions:

ROV Superintendent

Extensive knowledge and experience of running multiple ROV systems simultaneously on a deep sea pipe lay vessel, at least 10 years offshore ROV experience and a minimum of 3 years at Superintendent level.

ROV Supervisor

Extensive knowledge and experience of ROV supervising on multiple ROV systems with simultaneous operations on a deep sea pipe lay vessel, at least 8 years offshore ROV experience and a minimum of 3 years at Supervisor level.

ROV Sub Engineer

Have at least 5 years offshore ROV experience and a minimum of 2 years at Sub Engineer level.

ROV Pilot Technician

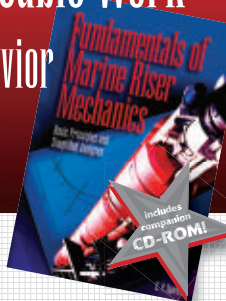
Have at least 3 years offshore experience at pilot technician level.

For future work, we would also welcome resumes from applicants with FMC Schilling Robotics ROV experience.

All applicants must be able to demonstrate ability to work in the USA on a permanent basis. If you feel you are suitable for any of these positions, please submit your resume to jobs@rovop.com

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Changing behavior in well control management

The recommendations from the International Association of Oil and Gas Producers following the Macondo well blow-out clearly called for a sharper focus on the technical content of well control training. Another priority issue was addressing human factors, including the competence and behaviors of the workforce.

A number of steps have been taken to address the technical shortfall. For its part, the International Well Control Forum reviewed its Drilling Well Control and Well Intervention Pressure Control syllabi, and new subjects were introduced around assurance of well integrity throughout the lifecycle of the well. These subjects included barrier management, casing and cementing, risk assessment, contingency management, and management of change.

In addition, technical taskforces were established to steer and shape exam content and questions.

The frequency of audits of training providers has also been increased. This was seen as a necessary step after issues regarding the consistency in training between centers and regions was identified.

However, the change in behavior of a global offshore workforce is more difficult to assess and measure.

The investigations found that through the chain of events, processes where people could challenge or take action were not always followed. It took a major fatal incident to place a global spotlight on standards and highlight the need for far greater consistency in training the people who are involved in well operations around the world.

A broader perspective on safety and particularly human factors is still needed to address the accountability issues experienced in the aftermath of the Macondo and Montara incidents.

A greater emphasis needs to be placed on empowering the workforce in the importance of their individual roles. This education should start at the most basic level with a focus on reaching out to students and those entering the industry for the first time. At the other end of the spectrum, it also needs to reach the high achieving engineers who have safety critical roles to play in drilling and well operations.

It is encouraging to see operators start to consider enhanced standards in drilling and well intervention. This is increasingly im-

portant as the industry ventures into increasingly hostile environments such as the Arctic and deeper waters. The enhanced content is more focused on learning from real well control incidents involving simulated exercises. It has been proven that team work and peer-to-peer review and feedback can deliver more dramatic results than classroom questions and answers.

Candidates undertake preparation in their own time including a technical refresher with advances in equipment ahead of the practical role play. They are then assessed in a similar manner as on a standard course, but can be expected to achieve higher results.

This preparation improves the capability of participants to anticipate and deal properly with all scales of a well control incident and encourages a more proactive approach to stopping the well flowing uncontrollably in the first instance. Exercises and critiques also include human factors behavioral sensitivity with a greater focus on crew resource management.

There is also growing recognition that it is just as important for people in onshore roles to get involved with well control training. Increasing knowledge around the reality of responding to a “well kick” or blowout situation offshore can help guide the support offered from onshore colleagues.

But the question remains around how you really measure a shift in behavior of a global workforce. There is a lack of unified data on the values, beliefs and expectations between oil and gas companies that could help to track any improvement. Hard and fast statistics on incidents and importantly the near misses are currently the best way to learn, but this information is not always shared.

An industry-wide effort is needed to further drive up competency. It will take a greater level of collaboration to achieve this. The first seeds have been sown, but over the months and years ahead we must unite to address the challenge of effecting a permanent change in safety behavior. The consequences of not doing this will damage the whole industry.

David Price
CEO

International Well Control Forum

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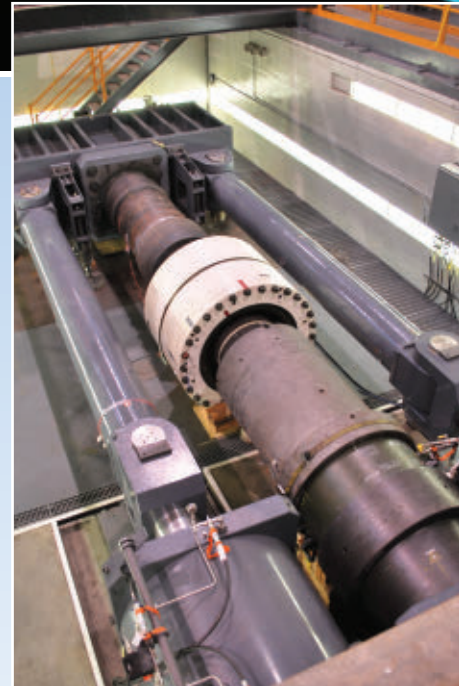
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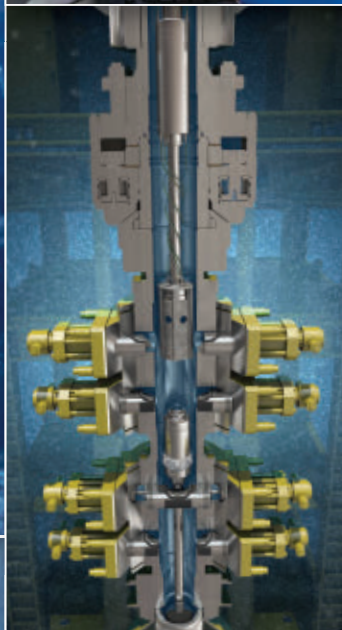
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BOLD PIONEERS OF THE NEW ENERGY FUTURE

After decades of holding a monopoly on both exploration and production in Mexico, Pemex, the country's NOC, will be just one of many companies bidding for blocks, thanks to the country's energy reforms bill formally becoming law on December 21st, 2013. Fifteen months later, and despite oil prices dropping to less than USD 50 per barrel, Mexico decided that it would still press on with its historic auction of offshore blocks. "The plunge in the price of oil is not negatively affecting the global interest in Mexico's energy industry opening, since we have production and development costs that are far below the price of oil, at USD 22 per barrel," explains Emilio Lozoya Austin, CEO of Pemex. "This makes Mexico a very attractive location to invest in." On December 12th 2014, Mexico's energy sector took a major first step towards private investment when it opened bidding on 14 shallow water exploration and production contracts, covering 4,222km² in Mexican territorial waters.

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PRODUCED BY FOCUS REPORTS.

Publisher: Ines Nandin

Coordinator: Alina Cotfasa

Contributions: Mariuca Georgescu & Angelo Basurto.

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However, while the exuberance currently electrifying the Mexican oil and gas sector is perhaps justified given developments over the last year, these new companies would do well to remember that a brave new world is dawning in Mexico, and the expertise of the old guard may not prepare companies sufficiently for new frontiers – a lesson that can be learnt from OGX in Brazil, among others.

DEMOCRATIZING THE ENERGY REFORMS

In recent decades, Mexico has done little to bust the monopolies and oligopolies that stunt the country's growth. The state's control of the energy sector, as well as private monopolies in other strategic sectors including telecommunications, have translated into increased basic costs for Mexicans by some 40 percent according to OECD estimates, although, as Lozoya points out, "Pemex's efforts end up building one out of every three schools, one out of every three hospitals, one out of every three kilometers of roads that are built." Indeed, with the opening up of the energy sector, the Peña Nieto administration has taken bold steps to act on the mandate for change that was handed to it in the last presidential election, and has made significant progress to dismantle these concentrations of economic power. Leveling the economic playing field will undoubtedly help to boost Mexico's development, particularly that of small and medium-sized enterprises, the job creators in most economies.

Some, however, have pointed out that at face value, it is big business that is far better positioned to benefit from the opening of the Mexican oil industry as a result of the size of the required investment. "The reforms represent a huge challenge for smaller and medium-sized Mexican companies," says Alejandro Fuentes Alvarado, director general of Detectores y Controladores Del Golfo S.A. de C.V. (DYCGSA). "Domestic businesses will be expected to compete with international business-

es that, in some cases, will have a mix of technological, financial and experiential advantages over us. I see this as a challenge, but also as a great opportunity that we should leverage to the fullest."

Despite these challenges, it is evident that Mexican businesses are

determined to rise to the challenge and are viewing the reforms more as an opportunity for growth, rather than a competitive threat. José Juan Altonar Reyes, director general of Altopetrum & General Oil de México, a domestic SME specialized in the provision of products and services in the area of solids and fluids control for the oil industry, shares his views about the opening up of the industry to international participation. "I most certainly view the reforms with great optimism. They represent a fantastic opportunity to develop our business into a stronger and more sustainable company."

Altonar goes on to explain how the liberalization of Mexico's energy sector will enable Mexican businesses like his to interact with international businesses, thereby exposing them to new ideas, ways of operating and doing business. "SMEs in particular, like Altopetrum, have a lot to gain," insists Altonar. "The reforms will incentivize us to develop the scope and capabilities of our businesses, effectively unlocking additional opportunities for us as we evolve."

Although large companies in Mexico have experienced a compound annual growth rate (CAGR) in dollar terms of 14 percent since 1993, the country has experienced mediocre growth in relationship to peer coun-



Emilio Lozoya
Austin, CEO,
PEMEX

tries like Brazil over the same time period. However, after a rough 2014 plagued by high inflation, economists expect a gloomy year for Brazil, whose GDP is forecasted to shrink by 0.5 percent in 2015. In contrast, Mexico had a 2.1 percent GDP increase in 2014, forecasted to pick up to an encouraging annual average of 3.7 percent in 2015-19. Research suggests that these differences in performance are attributable to entrepreneurship and the growth of small and medium enterprises (SMEs).

"In the past, a handful of companies dominated the sector in its entirety," explains Altonar.

"The energy reforms and new regulations effectively allow for a larger market in terms of investors and invest-




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WHAT IS LOZOYA LOOKING FOR?

Holding degrees in economics and law and a Master's in public administration and international development from Harvard, Emilio Lozoya Austin became the CEO of Pemex after heading the international affairs office for Peña Nieto during his campaign, and leading his transition team. He speaks to EnergyBoardroom about what Pemex is looking for from future international partners – for the full interview, log onto EnergyBoardroom.com.

Q: Beginning in 2015, Pemex is set to ink its first joint ventures with private and foreign oil companies. Generally speaking, what characteristics and attributes will Pemex seek in its partners as the company makes one of the first major action steps in its energy reform?

A: International oil companies and medium-sized oil companies across the world are very eager to work with us, because we are a leading global player, particularly in shallow waters. In deep water we have evolved technologically, and have a current success rate above 50 percent.

The oil industry needs to look at very long-term goals. Investment cycles in deep water are more than ten years, to recover the cost. In other types of reservoirs we might have longer or shorter term horizons.

But Pemex, considering that we have one single owner which is the State, has very long-term goals and very long-term investment cycles, and this is beneficial for our current and our potential partners.

With Round Zero we requested to retain exclusive rights to prospective oil resources of the areas we have the highest expertise. We will be focusing in the areas we have successfully been developing, but also have the opportunity to add joint ventures with other international oil companies to complement our investments.

In the end, our goal is to allow Petroleos Mexicanos to have enough reserves to ensure sustainability in the medium and long-term, while giving the market sufficient resources to develop through the private sector. We need to assure our company's growth and our place as a leader in the oil and gas industry in Mexico.

ment levels. Increased spending across the entire value chain will translate into countless opportunities for domestic and foreign businesses, small and large." It also translates into cash for state coffers. "Overall, as a result of the energy reform, Mexico expects to attract more than USD 50 billion in new private and foreign investment by 2018, including about USD 32 billion via the new partnerships with outside companies," Lozoya explains.



José Juan Altonar Reyes, General Director, Altopetrum & General Oil de Mexico

exercised its strong influence over the national company; training and new comers were few and far in between. Over time, Pemex was drained of its experienced people and had many of its key positions taken up by inexperienced individuals, despite their best intentions."

However, Aparicio goes on to explain that "what we see today is a growing pool of newer generations that have both the skills and the eagerness to transform Pemex into a nimble 21st century oil company. So long as there is a shift in mentality and in the outdated business-as-usual ways, I am confident that the newer generations at the helm of Pemex can and will bring about real change."

"Pemex is conveying a message of transformation that is consistent with the principles of the energy reform," says Arindam Bhattacharya, Schlumberger's president for Mexico and Central America. "Indeed, international partners looking to take advantage of the opportunities in Mexico should listen to these messages carefully. Pemex, and the E&P industry as a whole, is communicating its desire for international participation and investment. Instead of being apprehensive of international competition, Mexico welcomes it."



Arindam Bhattacharya, President Mexico & Central America, Schlumberger

FROM AN ENERGY REFORM TO A MINDSET REFORM

After nearly eight decades of strict national control, with Pemex at the top of the pyramid, Mexican businesses will need to transform their mindset to adapt to the new energy reforms, which will entail a brand new way of doing business, a new set of standards when it comes to competitiveness, a new set of partners to diversify away from Pemex, and a new set of challenges for both Mexican and international companies. Business-as-usual in Mexico is changing fast.

José Miguel Aparicio Ferrer, CEO of Cartermar de Mexico, agrees. "Change starts at home and from within and for us Mexicans, Pemex is home. Fortunately, newer generations of businessmen and leaders are heading the state giant. For many years, as the union

AN IPO AMIDST THE REFORMS

C.I.C.S.A - CORPORATIVO INDUSTRIAL Y COMERCIAL S.A DE C.V

/// We began the process of analysis and evaluation to become a public company in June 2012, when the energy reforms were just a good idea, far from the reality that it is today," explains Andrés García Castillo, CEO of C.I.C.S.A, a company specialized in cranes for the offshore segment. He believes the energy reforms will provide solid growth to his company, based on the fact that "the potential pool of clients which we can offer our services is sure to expand, thereby increasing our long term commercial opportunities and overall business sustainability."

Do such listings mark a shift in the way that Mexican offshore service companies will do business, now there will be more than just Pemex as a client? "There were several objectives to listing the company," García explains. "As well as giving us better access to financing, preparing for the listing also allowed us to institutionalize and better define process and access to quality information. The shift to corporate governance will help us develop and grow in the long term. We believe that everyone—from partners and customers to suppliers, financial institutions and our own employees—will benefit from a company that operates in a more transparent manner."

According to García, "listing on the Mexican exchange by local businesses is limited, with less than 150 companies listed. In fact, C.I.C.S.A will be the first company based in the state of Campeche to be listed on the local market. Nevertheless, the relative underdevelopment and lack of experience in the listing market will cause us to incur generally higher costs, with restricted consulting and advisory resources that are more likely than not unsuitable for our specific needs." If more Mexican companies in the oil and gas industry wish to list, they may well have to face the same challenges.

BEYOND INCREASED PRODUCTION

Although one of the primary aims of the energy reforms is to reverse Pemex's stubborn decline in production, from 3.5 MMb/d a decade ago to approximately 2.4 MMb/d today, the NOC has the chance today to enhance investment efficiency and operational productivity across the entire value chain by introducing higher levels of competitive forces.

For instance, earlier in 2014, Pemex was forced to cut production forecasts to 2.35 MMb/d by the end of 2014 after it was revealed that aging production systems were counting some water as oil. This was unwelcome news for the NOC, as it had already cut its output target earlier in the year, forecasting that production would fall to 2.4 MMb/d at 2014 by year-end after appearing to stabilize for a number of months at around 2.5 MMb/d. In response to these issues, Pemex sought to discover the best international technologies and practices to measure hydrocarbon flow and quality by organizing its first ever 'Exhibition on Hydrocarbon Flow and Quality Measurement' in November



Primo Luis Velasco Paz, Sub-Director of Distribution and Marketing, PEMEX

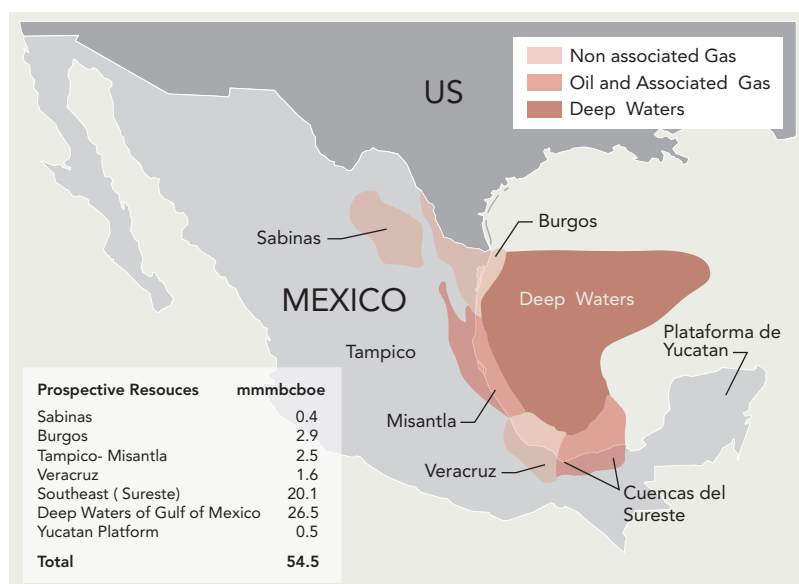
2014. As Primo Luis Velasco Paz, sub-director of distribution and marketing at Pemex and executive president of the Congress, puts it, "we intend to convey to both Pemex and businesses operating in that domain that we have hit the ground running and are prepared to make the necessary changes and investments to enhance our measurement accuracy and effectiveness made possible by the recently-introduced secondary laws."

Furthermore, he goes on to explain that Pemex is "looking to promote greater technological exchange among all businesses and attendees, in addition to Pemex's own employees, in order to raise awareness about the latest technologies and solutions. The topic of measurements and their implementation in Mexico is taking on an even greater importance in the domestic industry, particularly as a result of the energy reforms. Mexico's congress has made clear their objective to intensify technological exchange in the industry and this is precisely what the exhibition was about."

Alejandro Fuentes Alvarado, director general of DYCGSA, a Mexican company dedicated to the implementation of instrumented safety systems and measurement of hydrocarbons and attendee of the congress, shares Velasco's views. "Measurement is a very important area within the universe of the oil and gas business and this reform is bringing more and more projects each day," explains Fuentes. "In turn, this automatically translates into new business for our country. Businesses like DYCGSA must exert a constant effort and do their part to ensure that the country's infrastructure and operations are safe and efficient. The energy business model as we know it is based on the extraction and commercialization of oil and, to make that happen, previous measurements and calculations must be done and this is where we enter the picture. To put it bluntly, the more multinational companies want to enter the Mexican market, the more measurement must be done."

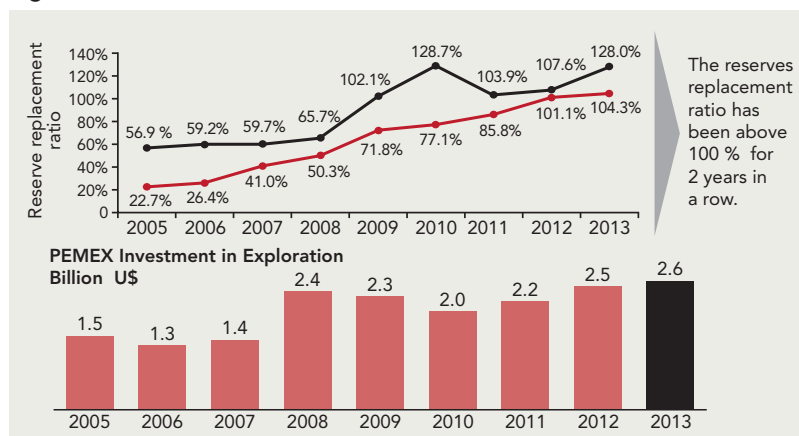
Fuentes explains that "Pemex is investing more in measurements each day as production decreases. They need to become more

Fig. 1: DISTRIBUTION OF MEXICO PROSPECTIVE RESOURCES (THOUSAND OF MILLIONS OF BARRELS OF CRUDE OIL EQUIVALENT)



Source: Secretary of Energy, Crude Oil Prospect 2012-2016

Fig. 2: PEMEX RESERVE REPLACEMENT RATIO



Source: PEMEX

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efficient at the extraction process to calculate everything carefully before doing any drilling begins. DYGCOSA helps them to become more productive in this regard and thus more profitable.”

Another area that the energy reform was created to address is energy sustainability and efficiency. As a Mexican company dedicated to providing integrated power generation solutions specifically to the oil and gas industry through the use of cutting-edge technology, Industrias Energéticas welcomes the energy reforms with open arms. The company is a recognized distributor for Capstone Turbine Corporation, the world’s leading producer of low-emission MicroTurbine systems, and offers clients advanced power solutions associated with the high levels of efficiency and ultra-low emissions.

Although there is burgeoning global demand for such innovative green products, for Juan Carlos Hernández Nájera, director general of Industrias Energéticas, introducing these greener and more efficient technologies to Mexico has not always been smooth sailing. “One of our key challenges was convincing clients to use our products since they were more on the premium side of power generation solutions and the regulations to promote the use of cleaner sources of power were lacking,” says Hernández. “Of course, we put a lot of effort into educating prospective clients not only of the environmental benefits of Capstone MicroTurbines, but also of their capacity to significantly re-



Juan Carlos Hernández Nájera, General Director, Industrias Energéticas

duce costs by reducing consumption as well as maintenance costs. With the enactment of the energy reforms, Mexico has made a meaningful shift towards more environmentally conscious solutions for the extraction and consumption of energy,” declares Hernández.

In reference to a slew of energy sustainability regulations and funds introduced by the energy transition package, which contains laws promoting sustainability, Hernández is optimistic about Mexico’s environmental footprint. “We are excited about the new regulations introduced by the energy reforms which seek to promote cleaner and greener practices,” affirms Hernández. “The environmentally friendly legislation will finally put an end to the ‘diesel-spilling’ culture that prevailed in the past when companies opted, for example, use the cheapest equipment which often was extremely polluting and wasteful.”

FREE ADVICE / PARTNERSHIP IS KEY

With a rich professional background in the international exploration business, José Miguel Aparicio Ferrer, CEO of Catermar de Mexico, an industrial catering and hospitality services company specialized in the oil industry, offers investors eager to participate in Mexico’s emerging

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opportunities a simple piece of advice. "In the same way that travelers to new destinations first seek to sample the local foods and visit the cultural centers of the host country to see it for what it is, investors should seek to reform partnerships with established local businesses. Working directly with Mexicans is undoubtedly the best way of ensuring that investors become a part of the country's historic energy reforms."

Surely, investors should not take this advice lightly. In the past, Catermar de Mexico has successfully acted as the legal representative of several drilling companies, including most importantly Pride International for which Aparicio was the legal representative and commercial manager for about a decade while simultaneously heading his catering business. During that time, Aparicio successfully contracted Pride rigs to Pemex that generated USD 1.1 billion of revenues over that period of time. "Now more than ever," Aparicio states, "for those international players looking to be a part of the Mexican energy reforms, it's rather simple; work with Mexicans!"



Yann Kirsch,
EVP Business
Development
Goimar

When asked about the biggest obstacles facing international investors looking to penetrate the Mexican oil industry, Yann Kirsch, executive vice president of business development at Goimar, suggests that "it's perhaps the cross-cultural differences and language barriers that are toughest to overcome." Part of the Goimar-Goimsa Group, Goimar is an organization dedicated to the leasing and operation of drilling rigs and marine vessels to the oil and merchant sectors which attributes a lot of its success to the wealth of experience in partnering with international players.

"Goimar's operational seed," explains Kirsch, "stems from 2002 when we were responsible for operating a semi-submersible drilling rig owned by Sinopec, which was then managed by Maersk contractors. We worked in close collaboration with Maersk on operating that drilling rig, and represented only the start of many strategic alliances with international organizations to offer a variety of offshore drilling services." Since then, Goimar has successfully partnered with a variety of leading international players including one of Asia's largest marine companies - Pacific Richfield Marine, China Oilfield Services (COSL), Colombian-based Coremar and CROSCO from Croatia, among many others.

"We gained a lot from those experiences," boasts Kirsch, which have allowed them to overcome the intercultural barriers to partnering with international players. "We have managed to eliminate these barriers and introduce Pemex to different kinds of companies from around the world to service their needs and target various international tenders or projects in the market place."

Kirsch goes on to add that, "in many ways, we like to think of ourselves as that bridge connecting Mexico and Pemex to the global arena. Most often, the best strategy for any company to enter a new market is through local partnerships. Doing so allows investors to bet-

UPPING THE GAME

As the reforms are well into their implementation phase and the industry prepares itself for the wave of international investment and participation, many businesses are looking to professionalize their organization. One way in which they are doing so is by gaining internationally recognized certifications that would enable them to meet the requirements of international businesses.

A prime example of these is Catermar de Mexico, a Mexican company founded in 1993, with the purpose of providing world-class industrial catering and hospitality services to the terrestrial and maritime facilities of the Mexican oil industry.

With over two decades of experience under their belt, José Miguel Aparicio Ferrer, CEO of Catermar de Mexico, explains that, "since the very beginning, we have been keen to building Catermar into a company capable of competing in the international arena. As a consequence, we are the first Mexican company to in our field to earn ISO 9000 certification for quality management systems as early as 1998. Over the years, our ambitions continued to be strengthened by improving installations, training and the services we offer to clients. In fact, we are currently in the final stages of having integral certification that would include ISO 14000 certification which addresses various aspects of environmental management, as well as OHSAS 18000 occupational health and safety certification the ISO 22000 standards which addresses innocuity of food. These standards will all be integrated into our ISO 9000 certification to demonstrate our commitment to quality throughout the organization."

"Having embarked on a mission to professionalize Catermar and gain international accreditation some two years ago, we are ecstatic to have successfully reached our goal," revels Aparicio. "When we first started that process, many around us scoffed at our ambitions and never saw the long term benefit. Today, we know that Pemex will soon start mandate that its suppliers in our field have these very same certifications, giving us at least a couple of years' head start over those that chose not to invest in the development of their business. Sure, we have had to sacrifice a good proportion of our profits, but this was done in lieu of being there first."



José Miguel
Aparicio, CEO
Catermar de
Mexico

ter navigate the unique characteristics of a given country's economic, financial, legal and political systems, among others."

PRE-REFORM INNOVATION DONE RIGHT

Before the energy reforms became a reality in Mexico, Pemex was already starting to experiment with different ways to break out of its traditional business lines and try to explore new opportunities within the constraints of laws that governed it. One of the fruits born from this activity was Comesa: initially created to provide Pemex with cutting-edge seismic acquisition technology, Comesa is a majority state-owned business, but has proven much more agile than its parent company, which has left it able to rapidly capitalize on market insight and opportunities available. For example, by 2007, Comesa had expanded its capabilities from an exclusively onshore company to providing offshore exploration services in both shallow and



Gustavo
Urdaneta,
Director of
Operational
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deepwater plays; by 2012, the company had moved into a fully-fledged production company too.

For Gustavo Urdaneta, Director of Operational Services at Comesa, it was clear that the energy reform was a necessary step for the Mexican oil and gas sector. "It was rather obvious that Mexico needed the participation of private companies," he says. "Our country did not have enough money to invest in the oil industry and in the development of new fields. Pemex required a lot of help in technically difficult and complex areas, such as in the Gulf's deepwaters for instance. I can see that companies all around the world have their eyes on Mexico." He is hopeful that the reforms will mean positive developments for Comesa. "The conditions are ripe for a transparent relationship between us and multinationals. The rules of the game are clear and the stage is being set for a greater production of crude oil."



Jorge Luis González Velázquez,
 General Director,
 GAID

Although it might seem today as if the pre-reform Pemex had been languishing in the dark ages when it came to innovation, there are great examples to be found of the NOC leading the way. Jorge Luis González Velázquez, the brain behind Grupo de Analisis de Integridad de Ductos (GAID), is credited with raising global industry standards thanks to a project run together with Pemex for improving pipeline lifecycles. "Metallurgy has always been of great interest to me," González explains, which ultimately led him to improve Pemex's oil and gas pipelines, which often corrode and crack due to the high levels of sulfur in Mexican crude. The mathematical algorithms developed by GAID allow for precise calculation of the remaining strength and life of pipelines, which has allowed Pemex to save money and work more efficiently on maintenance in the years since it was introduced as a standard test.

González's novel model became a landmark in the relationship between academia and industry in Mexico, because the scientific methodology came to be regarded as a "discipline now called integrity assessment, which nowadays is the worldwide standard for managing every maintenance activity in the oil and gas industry as well as many other fields," he explains.

Pemex also for many years before the reform worked with leading oilfield service companies on a quasi-incentivized basis. For companies like Schlumberger, this was an opportunity to develop a new set of skills according to the demands of the market. "Over the past few years, Mexico has also become a key market for our Integrated Project Management (IPM) business," explains Bhattacharya of Schlumberger. "Being among the first oilfield service companies to offer IPM solutions, for over two decades now, Mexico was one of the countries where we started managing some of the largest projects; starting with the development of the Burgos basin in the north of the country, down to Chi-contepéc and further south to Villahermosa's basins which are well-known for their complexity. From an IPM perspective, Mexico is an important part of Schlumberger's portfolio and will continue to be so, particularly as deepwater projects gain momentum in the country.