

3-D Takes On Growing Role In Future Of Subsea Inspection

The use of 3-D is quickly changing the way the oil and gas industry and the renewables sector assess and monitor critical subsea assets.

With pressure to deliver improved safety, operating efficiencies and reduced costs, 3-D does all three. Rovco's current photogrammetry offering is just the start. The future is live 3-D and artificial intelligence (AI) analysis. Rovco CTO Dr. Iain Wallace explained the advantages of 3-D to Hart Energy.

Hart Energy: What is the current norm for subsea inspection?

Wallace: It is video. The problem with that is that you carry out a survey and you get tens of hundreds of hours of video footage, which is hard to deal with from a practical standpoint. You have got to move terabytes of data around

[and] get it back to shore, which normally means you must wait for the vessels to come back. Then someone's got to sit and watch that. It's not a good way of doing things, but it's done this way because it's an easy way, if labor-intensive.

Hart Energy: Are there no advances in video analysis?

Wallace: In the future there clearly will be analysis of that video by computers. Why do they think this is even possible? The state of the art for computers looking at images is

that they are better than humans at specific tasks. There's no question about this. There's a big test called Image Net where there are about a million different images; a thousand different things could be in them. The computer's got to identify what's in it.

If you give that to a human who's never done it before, they'll get about 16% wrong; that's a human saying, "Is it a dog, or is this a cat?" The computer will do better. You can

train humans if they've had time to practice; that's fair enough. Then they'll get to about 6% error. A computer has 3% error, and it'll do thousands of images all day long. Computers, given the right setup, can be better than people at looking at images. That is fundamentally what a lot of the job is, so in this restricted setting there is the scope to apply all this technology to subsea.

Technology has seen huge investments from Facebook and Google; it's the same technology. You can do a Google Images search for something, and it'll find you pictures of that thing, right? Why can't I search for anodes in a video for example?

Hart Energy: What are you surveying subsea, and what are the expected outcomes?

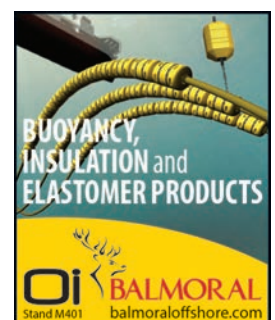
Wallace: [Companies] want to measure a risk. If they are surveying a pipeline, they want to understand if they



Rovco's services include 3-D modeling, like the 3-D model of a subsea dry-mate connector shown. (Source: Rovco)

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have free spans. How big are these free spans? That's a potential danger to the cable if it's not protected and if it's not safe from the seabed. And they want to understand this and if they need to do remedial work.

In an ideal world you'll build the thing, you'd leave it and it'd work perfectly for 50 years. Of course, that's not realistic; you must inspect it and you must ensure that it's fine. This is what they want. They're looking for anomalies. They're looking for what's wrong. Maybe what's right is part of that as well, but in a perfect system you would just flag only the things that are wrong. It would tell you exactly where they are, and then you'd do interventions only where they're required. And that's where the big cost savings are.

Hart Energy: So why is 3-D an advantage?

Wallace: Part of the reason is to get better data that's impossible to get from humans. For example, if you do a survey and you discover you've got a problem with anodes in one part of a wind farm. If you're measuring how much your protection is being used up on your wind farm, you will just sample a few anodes on a few of the different sticks because it's too time-consuming to look at them all.

Maybe you sample some that you didn't sample last year and discover a problem. You need to ask, 'Did that problem exist in all your historical data?' Are you going to get someone to look at your thousands and thousands of hours of video footage and say, 'Oh, yes, we did have that problem going back; we just hadn't spotted it.' It's getting this understanding, and that's where the analysis comes in.

It's why we're doing the 3-D bit as well because you need to know where these things are. It's all very well to say, 'I found a problem.' The next question is, 'Where is it?'

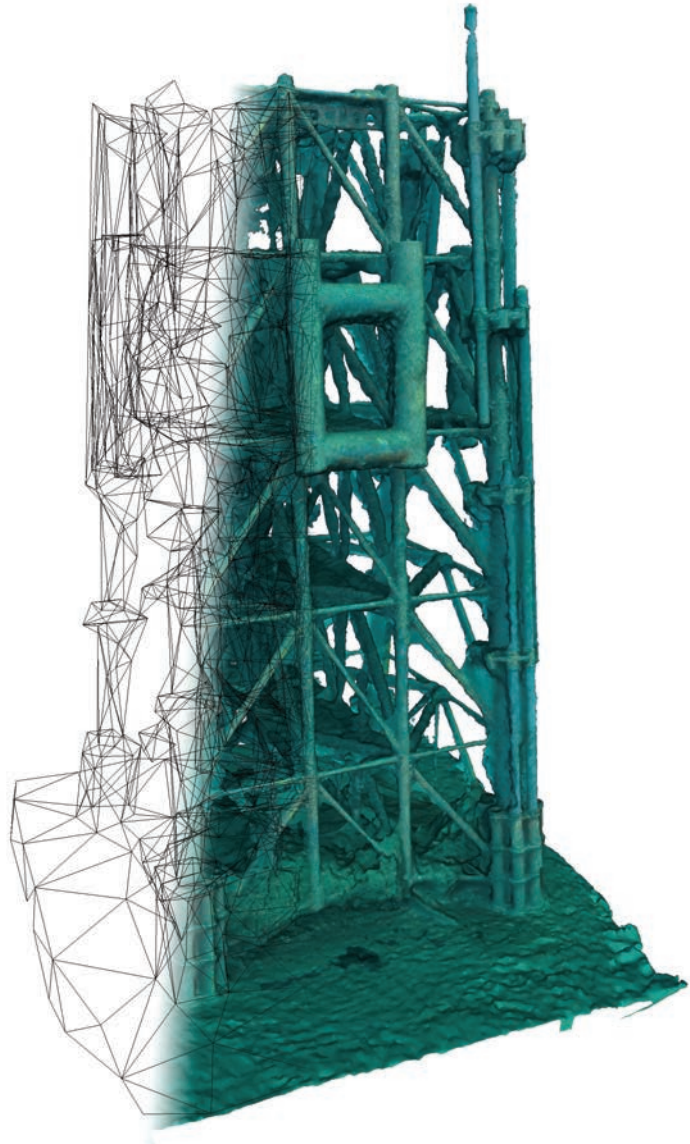
Hart Energy: Are your clients buying into 3-D surveys?

Wallace: We offer the post-process 3-D as a service to our customers. We do survey things you'd normally expect [such as] normal hydrographic survey operations and, then on top of that, if the client wants it, we can produce these 3-D models for them.

We're developing technology for live 3-D at the moment, and we have some ongoing projects around this, which we are planning on testing. I think our first tests started last summer, and we've got some final evaluation trials scheduled toward the end of the summer around August.

That's where we are with the live 3-D. The AI analysis is more of an ongoing thing because it's not necessarily looking at the live data; it's looking at historical video data as well, and that's something we're progressing alongside.

Hart Energy: What are the barriers to greater adoption?



A 3-D jacket mesh is depicted. Rovco was founded to bring AUV and ROV 3-D computer vision and AI technologies subsea. (Source: Rovco)

Wallace: The biggest challenge is it's naturally quite a conservative industry, and that's fair enough. It's no criticism. These are large expensive projects and large expensive assets, so you can't be irrationally rushing into things.

But the fact that it's recently become feasible to build these models to do the surveys, to analyze data and get useful information out, well, that's an easier pill to swallow because you're not convincing someone, 'Hey, do this totally new thing.' You're saying, 'We're going to do what you would anyway, the video survey, and we're going to produce this extra data.' Then that's a way that people can gradually come to the party.

Initially people might think, 'I'm still going to watch all the video footage anyway just in case the computer missed something,' but then eventually as it gets better and people get to the point of, 'OK, I'll only look at this video footage if there's a particular problem.'

I see there being a gradual change but a definite change.

—Mark Venables

DEVELOPMENT

Thailand's PTTEP Targets Zawtika Expansion

PTTEP International Ltd. (PTTEPI) is focusing on building 12 additional wellhead platforms to drill up to 240 wells in the Gulf of Mottama's Zawtika Field offshore Myanmar as part of the third and fourth phase development plan.

The development plan involves construction of four remote wellhead platforms as part Phase-1C and 12 wellhead platforms as part of Phase-1D, along with subsea pipelines and pipeline end manifolds near the producing fields developed during Phase-1A and Phase-1B.

The Thai company recently announced that it completed construction of the first of four wellhead platforms for Phase-1C, and the remaining three were "scheduled to set up in 2018."

"With a view to ensure future production of oil and gas resources, ongoing investment in oil and gas exploration activities is required," PTTEPI said in a report. "To sustain the current production rates of the Zawtika Project for supplying gas to both domestic and Thailand markets, installation of additional wellhead platforms and pipelines are required."

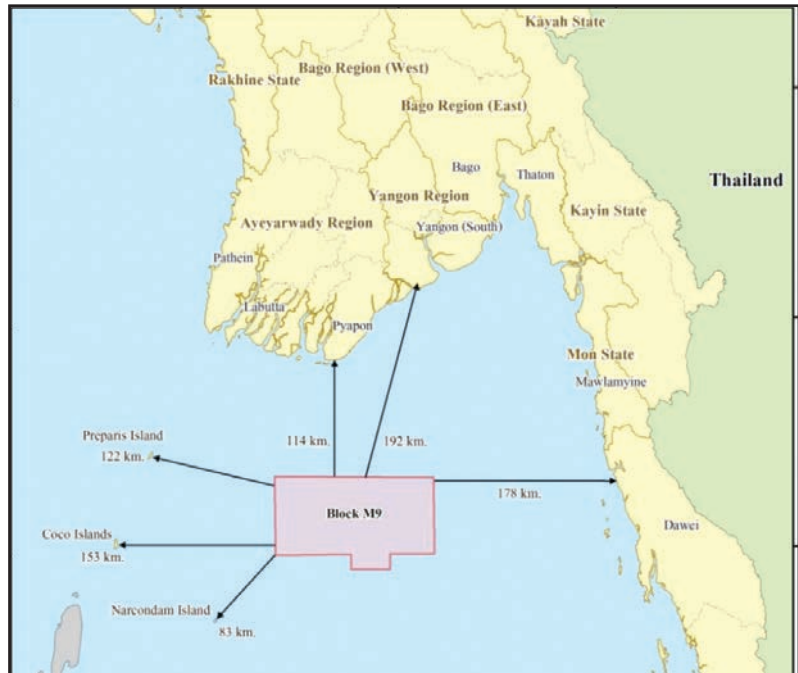
PTTEPI, an overseas arm of Thailand's state-run PTT Exploration and Production Co. Ltd., will launch Phase-1D in second-half 2020.

Discovered in 2007 the Zawtika gas field spans 11,746 sq km (4,535 sq miles) in Block M9 and is located in a water depth of between 135 m and 160 m (443 ft and 525 ft). The field lies about 300 km (186 miles) south of Yangon and 290 km (180 miles) west of Dawei on the Myanmar coast.

Development Plans

Phase 3 of development consists of building four remote wellhead platforms—ZWP8, ZWP9, ZWP10 and ZWP11—with four intra-field pipelines and two pipeline end manifolds.

The new wellhead platforms will consist of 20 well slots each through which gas/condensate wells will be drilled and completed with christmas trees and flowlines attached. The wells will be drilled to target depth between 2,300 m and 3,619 m (7,546 ft and 11,873 ft) in water depth of up to 160 m.



(Source: PTTEPI)

After this, the operator will launch the Phase 4 development plan for the field. This will involve constructing eight remote wellhead platforms—ZWP12, ZWP13, ZWP14, ZWP15, ZWP16, ZWP17, ZWP18 and ZWP19—with nine associated subsea pipelines and two pipeline end manifolds.

Well fluid from these 12 wellhead platforms will be transported to the Zawtika processing and living quarter platform via intra-field pipelines for processing, similar to the process for Phase 1A and 1B. Processed gas will be evacuated to an onshore center on Myanmar coast via existing offshore pipeline.

"The fixed structure of processing facilities and wellhead platforms were suitable for Zawtika development for water depth about 140 m to 150 m [459 ft to 492 ft] due to proven technology, cost optimization and shorter project schedule," the report said.

Higher Production

The projects aim to increase gas production at the Zawtika Field to 345 million standard cubic feet per day (MMscf/d) from about 300 MMscf/d by December 2017.

The operator currently produces gas from 36 wells in three prospects (Zawtika-4, Zawtika-5 and



Kakonna-3) developed during Phase-1A and 44 wells in three prospects (Zawtika-2, SPH-1 and Kakonna-1) of Phase-1B. The company built the Zawtika processing and living quarter platform, six wellhead platforms, intra-field pipelines and a 28-in. diameter, and a 230-km (143-mile) offshore gas pipeline to an onshore center at Ban-I-Tong.

About 80% of the produced natural gas from the Zawtika project is sold to Thailand through its oil and

gas company PTT, while the remaining 20% is sold to Myanmar companies.

The Zawtika Field is estimated to have nearly 57 Bcm (2 Tcf) of gas located in shallower reservoirs and Miocene-Pliocene Delta Front sandstones.

PTTEPI has an 80% participating interest in Block M9, while Myanmar Oil and Gas Enterprise holds the remaining 20%.

—Ravi Prasad

Aker Energy Buys Hess Ghana Business, Expects First Oil In 2021

Norwegian billionaire Kjell Inge Roekke's Aker Energy plans significant oil E&P in Ghana after a \$100 million deal to buy Hess Corp.'s business there.

Aker Energy said the proposed transaction, which is subject to approval from Ghanaian authorities, gives it a 50% stake in the ultradeepwater Tano Cape Three Points Block, which holds an estimated 550 MMboe and has the potential for a further 400 MMbbl.

Aker, Roekke's main listed investment vehicle, owns 50% of Aker Energy, while TRG, his privately held holding company, owns the remainder.

Aker Energy plans to present a development plan for the block this year, with production from the West African country expected to start in 2021.

"Ghana is still in the early days of developing its oil and gas resources, so for us, it means we can quickly build up there at a very exciting price," Aker CEO Oeyvind Eriksen told Reuters on the sidelines of an earnings presentation.

Eriksen likened the Ghanaian field to the Johan Castberg Field in the Norwegian Arctic as both having a breakeven price lower than \$35/bbl.

Roekke's TRG also is involved in a separate block in the area, which may provide additional resources to the development, Aker said, adding that the plan is to use an FPSO vessel.

Ghana is seeking to develop its oil and gas resources beyond its flagship Jubilee Field. Overall it was expected to produce an average of 200,000 bbl/d of oil in 2017, the country's deputy oil minister told Reuters in June.

The deal is the second between an Aker group company and Hess, following Aker BP's purchase of the Norwegian assets of Hess in a \$2 billion transaction.

When the field development plan in Ghana has been approved, Aker expects to draft financial or industrial partners into the project to help pay for it.

—Reuters

DEVELOPMENT BRIEFS

Woodside Looks To Offshore Gas Project For Growth

Woodside Petroleum launched a surprise \$1.96 billion share sale on Feb. 14 to raise funds to take control of and develop a long-stranded gas field off the country's west coast.

Woodside said it had agreed to pay \$744 million for ExxonMobil Corp.'s 50% stake in the Scarborough Field, a project that has been stuck on the drawing board for nearly 40 years due to factors including its remote, deep-water location.

The company said that soaring international demand for gas meant the time was right for the acquisition with the field expected to feed an expansion of its Pluto LNG plant in the state of Western Australia.

"The difference between supply and demand is opening up very, very quickly," said Woodside CEO Peter Coleman, adding that Chinese appetite for LNG was growing rapidly.

But some analysts underscored the challenges of developing the field, with Ben Wilson at Royal Bank of Canada describ-

ing the site in a broker note as "deep, distant, dirty and dry."

The move puts Woodside, seen as short on near-term growth prospects, in control of Scarborough with a 75% stake, working with BHP Billiton on a project now estimated to cost up to \$9.7 billion.

The rest of the money raised through the offer to existing shareholders will be used to support work on Scarborough, the Browse LNG project in Australia and the SNE oil development off Senegal.

The company also said it was pushing out a final investment decision on the Browse LNG project off Western Australia to 2021, a year later than last flagged and now estimated to cost \$15 billion to get to startup.

Kraken Costs Fall As Production Rises

The Kraken oil field in the U.K. North Sea already has delivered the 50,000 bbl/d of gross production operator EnQuest targeted, the company said in its latest operations update.



EnQuest continues to bring down costs at the Kraken oil field in the North Sea. (Source: EnQuest)

“Since late December all DC3 wells have been brought online and operational efficiency has significantly improved,” EnQuest said.

In addition, costs for Kraken—which reached first oil in second-quarter 2017—have fallen thanks to lower market rates for the remaining subsea campaign. After renegotiating drilling rig terms in early 2018, EnQuest said it will save about \$60 million of net cash payments for capex in 2019, which lowered the full-cycle gross project capex by about \$100 million to about \$2.3 million. That’s more than 25% below what was originally sanctioned, according to EnQuest.

“The DC4 well campaign, which was not anticipated to impact 2018 production, is expected to commence in the second half of 2018, with first production in 2019,” the company said. “A scheduled shutdown of approximately two weeks is planned for April, primarily to undertake performance improving work scopes and minor commissioning activities.”

Another maintenance shutdown is scheduled for September. It is expected to last about one week.

Eni Says Zohr Production Could Reach 2.9 Bcf/d By 2H 2019

Production from Egypt’s huge Zohr offshore gas field in the Mediterranean will reach 82 MMcm/d (2.9 Bcf/d) by mid-2019, Eni said.

Speaking at an industry event in Cairo, CEO Claudio Descalzi said the goal was to reach output of 51 MMcm/d to 56.6 MMcm/d (1.8 Bcf/d to 2 Bcf/d) by year-end 2018 and then ramp up to 82 MMcm/d by mid-2019.

Discovered in 2015 by Eni, the field contains an estimated 850 Bcm (30 Tcf) of gas.

Descalzi confirmed that by mid-2019, seven trains would be operating.

Egypt has been seeking to speed up production from recently discovered fields with an eye to halting imports by 2019 and achieving self-sufficiency. The country’s petroleum minister said on Feb. 12 that Egypt’s current gas production stood at 156 MMcm/d (5.5 Bcf/d).

Asked how many cargoes Egypt needed to fill the supply gap after a current tender for LNG is held, Tarek El Molla said, “very few.”

On the recent discovery of a natural gas field off Cyprus, Calypso 1, Descalzi said an appraisal well would have to be drilled to understand the real volumes there and that Eni would decide alongside Total when to drill that well. Asked whether it is believed to hold about 170 Bcm to 227 Bcm (6 Tcf to 8 Tcf) of gas, Descalzi said, “It could be more in that range. ... For sure it cannot be less, but we have to understand it.”

He added, “It’s a good find that has merit to go ahead with additional investment.”

ProSep Lands Services Contract For Johan Castberg Project

Integrated process solutions provider ProSep said it will supply three ProSalt units to Statoil for the Johan Castberg field development project located on the Norwegian Continental Shelf in the Barents Sea.

ProSalt technology, which utilizes ProSep’s multiphase adjustable extreme mixer with injection (MAX+), is used for crude oil and wash water mixing upstream of the desalting process. The mixer provides high-efficiency mixing of wash water and crude to meet the required outlet specification for crude export.


Tubular Bells
First Oil
November
2014






Lucius First Oil
January 2015





Jack/St. Malo
First Oil
December
2014



Three Successful Startups, One Common Denominator

Leader in Topsides Design

The Johan Castberg project was notably the biggest offshore oil and gas development in 2017, with an estimated cost of about \$6.2 billion. The scope of work consists of a production vessel, 30 wells, 10 subsea templates and two satellite structures with the capacity to recover an estimated 450 MMboe to 650 MMboe.

The project is anticipated to begin in 2022.

BP, Kosmos Move Closer To Senegal, Mauritania Offshore Project

BP and Kosmos Energy have moved closer to approving development of the Tortue natural gas field offshore Mauritania and Senegal after the two West African countries agreed to split production from the cross-border field.

Kosmos said it expected to make a final investment decision (FID) on the project in 2018, with first gas expected in 2021. BP had previously indicated it expected to reach an FID on the project toward the end of this year.

The Greater Tortue Complex, which straddles the maritime boundaries of the two countries, is estimated to hold more than 708 Bcm (25 Tcf) of gas. The production is expected to be exported via an LNG facility.

Senegal's President Macky Sall signed an inter-governmental cooperation accord on Feb. 9 with his counterpart in Mauritania, Mohamed Ould Abdel Aziz, during a state visit.

Kosmos said the agreement provides development of Tortue through cross-border unitization, with a 50:50 initial split of resources and revenues, and a mechanism for future equity redeterminations based on actual production and other technical data.

Enpro Subsea, Tullow Oil Ink Frame Agreement For West Africa

Aberdeen-based Enpro Subsea has been awarded a frame agreement contract to support Tullow Oil as part of the operator's strategic activities in Ghana, the company said.

The contract will see Enpro deliver its subsea intervention technologies to support Tullow's plans with new and existing wells in the Jubilee and TEN fields.

The campaign will see a consignment of up to 15 of its patented flow access modules being deployed in phases during 2018 and 2019 to facilitate a range of immediate applications, including multiphase metering, scale squeeze and acid stimulation in addition to potential future applications like fluid sampling and water cut metering.

The flow access system provides capital efficient, fast-track field development using standard subsea hardware. The work will continue to be delivered by Enpro personnel as they work toward establishing a permanent presence in the region.

Aker Solutions Wins Services Contract From Petrobras In Brazil

Aker Solutions has won a contract to provide maintenance and modifications services for three platforms at Petrobras-operated oil and gas fields offshore Brazil, expanding its business in a key international market.

The four-year contract is valued at about \$101 million and includes an option for a one-year extension.

The order covers a range of services to renovate, repair and upgrade the FPSO unit at the Barracuda, Caratinga and Albacora Leste fields in the Campos Basin. It also entails management at the yard where replacement parts and other equipment will be fabricated.

The company will execute the work from its CSE Mecânica e Instrumentação Ltd., a services base in Macaé, Rio de Janeiro. Aker Solutions acquired a majority stake in CSE in December 2016.

The work starts in March 2018, with final deliveries scheduled for first-quarter 2022.

—Staff & Reuters Reports

EXPLORATION BRIEFS

US Sets Largest Offshore Oil, Gas Lease Auction For March

On Feb. 16 the Trump administration said it would offer the largest oil and gas offshore auction in U.S. history on March 21 for areas in federal waters off the Gulf Coast, less than a year after a similar sale yielded little corporate interest.

The Interior Department said it would offer 77.3 million acres offshore Texas, Louisiana, Mississippi, Alabama and Florida for oil and gas development, an auction that includes all available unleased areas in the Gulf of Mexico. The blocks are from 5 km to 372 km (3 miles to 231 miles) offshore and in waters 3 m to 3,390 m (9 ft to 11,115 ft) deep.

The department announced the auction in October, without an exact date. The sale is in support of President



Oil platforms are positioned in the U.S. Gulf of Mexico. The U.S. government is gearing up for a lease sale in March. (Source: Shutterstock.com)

Trump's America-First Offshore Energy Strategy, which aims to reduce energy imports and boost jobs in the industry.

But offshore drilling is expensive in a time of relatively low oil prices held in check partially by plentiful supplies of onshore petroleum, which is cheaper to produce.

A lease sale in August last year got a tepid response from oil companies. The offer of 73 million acres received \$121.14 million in high bids for 90 tracts covering 508,096 acres.

The Bureau of Ocean Energy Management spokesman John Filostrat said the Interior Department hopes for "a healthy number of bids, more so than we did in August."

Egypt Signs Seismic Survey Deal With Schlumberger

Egypt has signed a deal with Schlumberger to conduct a seismic survey in the Gulf of Suez, the oil ministry said, part of efforts to encourage firms to invest in exploration work in the area.

The oil ministry announced an agreement with an international company on Feb. 12 to conduct a seismic survey of the Gulf of Suez to attract exploration investment but did not identify the company and gave no details.

The deal, signed on the sidelines of an energy conference in Cairo, allows Schlumberger to start work on the survey. The ministry did not give the value of the deal.

Egypt has been on a drive to attract more investment in its energy sector and speed up production at recent discoveries to become gas self-sufficient by year-end 2018.

"The region is still full of promising petroleum prospects that require further work and studies to rediscover the Gulf's petroleum reservoirs and those that have not yet been discovered," Tarek El Molla, Egypt's petroleum minister, said in a statement.

Molla also oversaw the signing of another agreement with Schlumberger that included a data center on areas open for exploration in Egypt, also part of the country's efforts to make it easier for foreign companies to invest in exploration work.

BHP Billiton To Drill Two New Deepwater Wells In Trion This Year

Drilling of a new appraisal well and a separate exploration well in the BHP Billiton deepwater Trion project will begin later this year, part of a plan approved by Mexican regulators on Feb. 15 that also revised downward the project's estimated oil and gas resources.

Australian mining and oil giant BHP Billiton won the rights to operate Trion in late 2016, taking a 60% stake in the project valued at some \$11 billion, while Mexico's state-owned oil company Pemex holds the remaining 40%.

The project marked the first-ever deepwater joint venture partnership for Mexico's newly opened oil sector following a constitutional energy overhaul in 2013.

Drilling for the new exploration well is scheduled to begin in October, part of BHP Billiton's obligations under the 35-year license contract it signed with the Mexican government.

The four-year exploration plan sets out three potential well locations, all west of the two original

Trion wells previously drilled by Pemex in 2012 and 2014 and at different depths. The plan also calls for the operator to drill a separate appraisal well in the part of Trion discovered by Pemex, which a company official speaking on background said will begin between August and October.

The Trion Block, which is located some 2,570 m (8,430 ft) below sea level, lies just south of the U.S.-Mexico maritime border in the Gulf of Mexico's Perdido Fold Belt. The exploration plan also calls for a range of geological studies as well as the acquisition and processing of new 3-D seismic data.

India To Auction 60 Small Discovered Oil, Gas Fields

India will auction 60 discovered small oil and gas fields with the potential to produce 194.65 million tonnes of oil and oil equivalent gas, the government said Feb. 7.

Blocks that will be auctioned were originally controlled by Oil and Natural Gas Corp. and Oil India Ltd. The fields have remained undeveloped for years due to their small size and the high cost of development.

India, the world's third-biggest oil consumer, imports nearly three-quarters of its energy requirements, but Prime Minister Narendra Modi has set a target of cutting its fuel import dependency to two-thirds by 2022 and to half by 2030.

India's previous auction of discovered small fields in 2016 was dominated by small Indian bidders.

Eni, Total Find Natural Gas Offshore Cyprus Near Zohr

Eni and Total have discovered a promising natural gas field off Cyprus, Eni said Feb. 8, saying the find looked geologically similar to the mammoth Zohr Field offshore Egypt.

Further analysis was required to determine the range of gas volumes and define further exploration and appraisal operations, Eni said.

"Calypso 1 is a promising gas discovery and confirms the extension of the 'Zohr like' play in the Cyprus Exclusive Economic Zone (EEZ)," Eni said in a statement.

Eni is the operator of the offshore block with a 50% participation interest, while Total is a partner with the remaining 50%.

The Italian oil and gas group reported the Zohr discovery in 2015. Located in the Egyptian offshore Shorouk Block about 190 km (118 miles) north of Port Said, Zohr holds an estimated 2.5 Tcm (30 Tcf) of gas, the largest ever discovered in the Mediterranean.

In Cyprus' waters, Calypso is an estimated 80 km (50 miles) away.

In Nicosia, Cypriot Energy Minister Yiorgos Lakkotrypīs said an "extensive column" of clean natural gas was discovered.

"This is a particularly positive development because it is the second substantive discovery in the Cypriot EEZ, which increases the reserves of Cyprus in natural gas," Lakkotrypīs said, referring to an earlier discovery of about 142 Bcm (5 Tcf) in 2011.

—Staff & Reuters Reports

TECHNOLOGY

Flow Assurance Evolves

Making sure oil and gas flow freely through long, complex tiebacks is one of the critical challenges of production facilities. Many things can inhibit flow, including hydrates, paraffins, scales and asphaltenes, and these impediments can affect producing wells, flowlines and production facilities.

This problem impacts both onshore and offshore developments. Onshore, it is easier to deploy equipment and address flow issues, but offshore flow assurance challenges are somewhat more complicated because intervention costs increase with the distance from shore and the length and depth of flowlines. Temperature also can present a challenge because temperatures in deep water often are near or below 4.5 C (40 F).

Many companies have invested in R&D to develop ways to improve flow assurance, investigating such techniques as insulating pipelines or electrically heating lines to manage temperature and introducing chemicals to control wax and anti-agglomerators to prevent hydrates from forming plugs.

Flow Assurance

There are multiple ways of remediating blockages. Flow can be modified so a specially designed pig can be deployed to cut through flow-restricting buildup and help improve throughput. The line can be heated, hot fluid can be circulated through the line, and coiled tubing (CT) can be inserted through a lubricator on the surface to deliver inhibitors like glycol or methanol into the face of the blockage.

A paper presented by FMC Technologies at the Offshore Technology Conference a few years ago identified and evaluated 30 flow assurance solutions, dividing them into five categories. Under “thermal solutions,” the authors included insulation, direct heating, electrically heated pipe-in-pipe, cold flow and phase-changing materials. Nine “chemical solutions,” ranging from thermodynamic hydrate inhibitors and low-dosage hydrate inhibitors to defoamers, H₂S scavengers and drag reducing agents, were included, as were “operating solutions,” such as pigging, flushing, depressurization and gas sweeping. There were “evaluations” of nearly a dozen “hardware solutions,” including subsea separation, boosting, compression and cooling as well as acoustic sand and leak detectors, desanders and CT tractors. The final category identified software that can evaluate impediments to flow and provide treatment options.

Hardware In The Line

Warrior Energy Services, a fully owned subsidiary of Superior Energy Services, offers a CT tool called CoilTac, a thruster designed for cleanout operations in pipelines with an inside diameter (ID) of 3 in. and larger. It has been used to distances in excess of 1,219 m (40,000 ft). The



The CT-deployed CoilTac tool has been used to distances in excess of 1,219 m to remove paraffin, hydrate plugs, asphaltenes, scale and other blockages to the full ID of the pipeline. (Source: Superior Energy Services)

thruster removes paraffin, hydrate plugs, asphaltenes, scale and other blockages to the full ID of the pipeline. Operations can be performed from liftboats, deepwater vessels, platforms or on land. The system provides jetting ahead of the thruster while applying thrust force as it moves down the pipeline.

Simultaneously thrusting and jetting ahead of the tool with treatment chemicals applied directly to the pipeline obstruction allows the thruster system to clean farther than conventional CT applications. The tool sends data as it progresses through the line, providing a snapshot of current conditions. The company believes this technology also could impact future pipeline construction design by extending the reach of subsea tiebacks.

GATE Energy's eelReel is another CT-deployed tool that has been used to resolve blockages, including hydrates, scale, paraffin and asphaltenes, as well as prejob stimulation, production enhancement, flowline abandonment and stuck pig retrieval. The tool is attached to CT and loaded into the flowline through an injector head positioned above the tree.

Power fluid (e.g., produced oil, diesel, chemical or water) enters the tool through the screen and pushes the tool through the line. High-pressure jets dispense the power fluid to remove debris, which enters through the tip and is extracted to the surface through the CT. The reverse screen subs on the front of the tip prevent debris from plugging the CT. According to GATE, eel-Reel jets clean the flowline to the original pipe ID.

Science And Art

Because oil and gas is a data-driven industry, there has been a shift toward using modeling software that can evaluate a range of parameters that affect hydrocarbon flow.

Instead of providing discrete solutions, oilfield service companies are developing systems that use data specific to the individual field to model hydrocarbon flow, determine where flow is likely to be inhibited and provide a range of solutions for restoring movement. Managing flow assurance has become both a science and an art that takes into account pressure and temperature profiles and uses a broad range of data to model hydrocarbon flow throughout the production system.

Production challenges are being simulated in laboratories, where hydrates, paraffin, asphaltene, emulsions, scale and corrosion can be studied in the context of a system. Using fluid flow software packages, engineers can evaluate the thermal hydraulic behavior for a wide range of systems and choose from an assortment of solutions.

Assured Flow Solutions LLC is one of the companies that offers a range of fluid flow testing capabilities to identify the multiphase flow challenges that are likely to occur during specific operating scenarios and provide a solid understanding of the transient behavior in a system. With this information in hand, engineers integrate reservoir, flowline/pipeline, riser, facilities, material and operational constraints to deliver a complete flow management system.

Having more data in hand to make decisions for improving system fluid flow is crucial to an appropriate life-of-field design; so it is not surprising that a number of companies are offering modeling as the foundation for understanding flow assurance issues and using the results to deliver solutions.

Schlumberger's PIPESIM is one of these. It is a steady-state multiphase flow simulator that offers workflows for both front-end system design and production operations. The PIPESIM simulator often is used to identify situations that require more detailed transient simulation such as shut-in, startup, ramp-up, slugging, hydrate kinetics and wellbore cleanup. Advanced simulation is carried out using the OLGA multiphase flow simulator, which

enables key flow simulation applications, including liquids handling, sizing separators and slug catchers, solids management, and pigging modeling for contingency planning. By identifying areas prone to slugging, corrosion and solids formation, engineers are able to pinpoint solutions appropriate to each particular flow challenge.

Halliburton's SureStream flow assurance services, which the company refers to as "integrated flow optimization capability," is another broad offering of flow assurance solutions. Through the SureStream suite of services, engineers provide analysis and assessment of an extensive range of parameters that impact the free flow of production and offer a range of chemical, mechanical and thermal cleaning programs as well as maintenance management support.

Baker Hughes, a GE company (BHGE), addresses flow assurance issues with FORSA flow assurance chemical solutions. BHGE uses what it calls a total systems approach process to analyze field conditions from the reservoir to the wellhead up to the surface storage tanks with the goal of identifying flow challenges and formulating the optimal mitigation option. After pinpointing potential threats, BHGE engineers can offer a solution from options that include scale mitigation treatments, paraffin control, asphaltene treatments and hydrate inhibition.

Tools For Tomorrow

There is a lot at stake when hydrocarbon flow is curtailed. Not only does restricted production impact profitability, it can result in compromised or damaged equipment that can threaten the environmental integrity of operations.

As operators focus on improving safety and minimizing the footprint of offshore production, longer tiebacks and more subsea systems will be the norm. More real-time production data will be available, and creative engineers will mine that information to find even better ways to improve flow assurance.

—*Judy Murray*

TECHNOLOGY BRIEFS

Aker Solutions Partners With Cognite To Strengthen Digital Offering

Aker Solutions has agreed on a long-term collaboration with software company Cognite to accelerate the development of digital solutions that will drive major efficiencies through the entire life of an energy asset.

The energy services company will use Cognite's advanced industrial data platform to collect and analyze large volumes of data from offshore energy installations, providing solutions that will enable customers to make informed decisions about an energy asset at any stage of its lifetime. This will reduce costs, lower risks and improve performance.

"Capturing and organizing large volumes of complex industrial data is crucial to realizing the full potential of digital technologies," Astrid Onsum, Aker's chief digital

officer, said in a news release. "Cognite's data platform will enable us more rapidly to provide even better products and services for our customers."

Cognite's platform aggregates and structures vast amounts of data from all types of industrial systems ranging from real-time sensors to equipment hierarchies, maintenance logs, process diagrams and 3-D computer-aided design models.

The collaboration with Cognite strengthens Aker Solutions' push to develop digital solutions that help integrate different parts of an oil and gas field with a clear vision toward automated field development and engineering, smart-products offerings and new services enablement.

The company also recently formed Software House, an internal initiative that will build on Aker Solutions' existing technology to develop new software products for energy assets.

NEL Focuses On New 2-D Flow Visualization Technology

NEL, a flow measurement R&D specialist, has the first laboratory in the world to invest in 2-D flow visualization technology, a press release stated.

The new technology uses 2-D X-ray tomography to produce high-definition images of complex multiphase flows, which cannot be captured with conventional instruments. This more precise reproduction of flow patterns will optimize meter design against specific operating conditions, ensuring greater measurement

accuracy, reducing uncertainty and minimizing operators' financial exposure.

NEL's system is designed primarily for measuring multiphase flows in horizontal and vertical pipes and will be capable of determining the 2-D phase fractions within a multiphase pipe flow in real time. It also offers extremely high-frequency data capture of more than 150 frames per second, delivering detailed tomographic reproduction of the cross-sectional phase distribution (e.g., oil, gas and water) within the flow regime.

—Staff Reports

FLOATER BRIEFS

Kvaerner, Aker Solutions Land Contracts For Johan Castberg FPSO Unit

Aker Solutions will supply two modules for water and chemical injection for the FPSO unit at Statoil's Johan Castberg development in the Barents Sea in a \$57.8 million deal.

The modules will be built at Aker's Egersund yard on Norway's west coast. The company's Sandnessjøen facility in northern Norway will provide smaller modules for the FPSO unit and a flare boom.



Aker Solutions, a subcontractor for Kvaerner, will supply modules for Statoil's *Johan Castberg* FPSO unit in the Barents Sea. (Source: Statoil)

Aker Solutions is a subcontractor of Kvaerner, which recently agreed to deliver topside modules for Statoil's *Johan Castberg* FPSO unit as well as the hookup and integration of the modules with the hull. The contract is valued at about \$481 million.

Kvaerner said its scope includes fabrication of the topside modules with most of the modules being delivered from Norwegian yards. The company's Stord facility will fabricate the modules for gas injection, separation and for the recompressor, while Kvaerner's specialized facility in Verdal will fabricate the module for seawater handling and the main pipe rack.

At its peak, the scope for the FPSO vessel will involve about 2,000 Kvaerner employees and subcontractor personnel, Kvaerner said.

As subcontractor to Kvaerner, Aker Solutions' yard in Egersund will deliver the modules for water and chemi-

cal injection, while the company's facility in Sandnessjøen will deliver smaller modules and the flare boom, Kvaerner said in a news release.

The hull, including the living quarter fabricated for Statoil by Sembcorp in Singapore, will be delivered to Kvaerner's Stord facility in fall 2020. Installation of all modules and integration will start immediately after arrival of the hull. The FPSO unit will be fully completed including commissioning and testing at Stord before the planned sail-away to the field in first-quarter 2022, according to the release.

Kvaerner said the initial project planning will start immediately, and fabrication will begin fourth-quarter 2018.

In addition, Kvaerner said it plans to invest about \$46.8 million to upgrade its yard facilities at Stord, pending approval by the company's board of directors. The upgrade will include a new deepwater quay and extension of the crane rail, which will allow the large 1,050-ton gantry crane to cover most of the *Johan Castberg* FPSO unit, according to the release.

Bluewater Extends Contract For Floater Fleet Services



The Aoka Mizu FPSO unit, designed and built by Bluewater, is shown. (Source: Bluewater)

Bluewater Services (U.K.) Ltd. has awarded Fabricom Offshore Services Ltd. a two-year contract extension to a framework agreement for engineering, procurement, construction (EPC) and associated services for the company's global fleet of FPSO vessels.

U.K.-based Fabricom is a subsidiary of ENGIE Fabricom UK and provider of fully integrated EPC delivery solutions for the oil and gas industry. The contract exten-

sion builds upon a business relationship that dates back to 2013, Fabricom said.

—Staff Reports

VESSEL BRIEFS

Southern Ocean Firms Up Work In Asia-Pacific Region

Oceanteam said construction support vessel (CSV) *Southern Ocean* has secured a new contract and will start operations by mid-February 2018 for 30 days with an option to extend for 60 days.

The CSV has been assigned to multiple smaller projects within the Asia-Pacific region. *Southern Ocean* is a dynamic positioning class 2 CSV with large cranes (1 by 250 and 1 by 100 tonnes fully heave compensated), 2,400-sq-m (25,833-sq-ft) deck space, 10 tonnes deadweight, extensive accommodation and seafaring capabilities. These characteristics enable *Southern Ocean* to be utilized for field support, construction and installation.

The vessel can carry 7 tonnes load on deck, combined with in-house carousel, reel and engineering capabilities. The vessel also can be utilized for a flex-lay project in the oil and gas, power and offshore renewables markets.

Southern Ocean is owned by a joint venture between Bourbon Offshore Norway and Oceanteam.

GC Rieber Shipping Books *Polar Queen* For Summer Campaign

GC Rieber Shipping said Feb. 16 it has entered a time charter agreement with a European offshore client for the construction support vessel *Polar Queen* for four months with options to extend by up to one month.

With this charter, all GC Rieber Shipping subsea vessels have secured contracts for the summer of 2018.

The *Polar Queen* will be used in British sector to perform walk-to-work duties and commencement will be in May 2018.

“With this charter, GC Rieber Shipping is sold out for the summer of 2018,” said GC Rieber Shipping CEO Christian W. Berg. “Both *Polar King* and *Polar Onyx* are now on solid long-term charters, and the agreement for *Polar Queen* proves the robustness of our crew and organizational capabilities.”

—Staff Reports

SUBSEA EXPO

Initiative Takes Aim At Developing Small Pools



Chris Pearson

The Oil and Gas Technology Centre’s (OGTC) “Tie-back of the Future” initiative aims to halve the cost and time to develop small pools, making an additional 400 MMbbl economic.

The initiative, which was discussed during this year’s Subsea Expo, brings together 25 operators, supply chain firms and technology developers to transform the approach to developing marginal fields. Creating a circular economy, whereby subsea equipment is designed for disassembly and reuse, is at the heart of the initiative.

Core to the project is the circular economy, a process that views waste as a resource such as recycling material and reusing system components. In this case, it involves recovering, refurbishing and reusing subsea architecture among field developments. Although this is difficult for current subsea systems, a change in mentality during the design phase can make it possible for future developments. OGTC is looking at reusable pipelines that use

new installation and joining methods and materials such as composites, reusable control systems and advanced flow management.

According to Chris Pearson, small pools solution center manager for the OGTC, the circular economy talks about a different commercial model. “We phrase it as design for disassembly not decommissioning,” he said. “Rather than thinking of decommissioning as a liability, it can become a commercial opportunity. If you have designed the kit to be manufactured, installed, recovered, reconditioned and reinstalled, you create many commercial opportunities.”

To date, OGTC has invested £250,000 (about US\$349,812) in engineering activity to develop the initiative, five technology projects are underway, 13 technology proposals are in the pipeline and six integrated studies have been completed. Industry support from operating and supply chain companies is required to make the “Tie-back of the Future” a reality.

Chasing The Small Pool Prize

The U.K. has 3 Bbbl in technically recoverable but stranded resources. “At current exploration rates, it would



The U.K. has 3 Bbbl in technically recoverable but stranded resources. (Source: Shutterstock.com)

take 14 years and 500 wells to discover this same volume,” said Mhairidh Evans, principal analyst for Wood Mackenzie. “As an ultra-mature region, this level of discovered resource can no longer be ignored.”

It is Evans’ belief that the market is now ready to start exploiting these assets. “A few things came together at the end of last year that made it a bit more important. The 30th round was coming up, [and] the corporate landscape of the North Sea was changing. Folks were looking at projects in a different way. Short-cycle, quick payback projects are a bit more in fashion.”

Wood Mackenzie estimated there are about 110 platforms or floaters where more than one field ties into it. “In our view 50% of those hubs have an economic life of five years or longer ahead of them,” Evans said. “If we move forward to 2025, we can see a situation where we are down to 10 to 15 of these infrastructure hubs still having a decent economic life ahead of them. The days of adding new infrastructure to the North Sea are not quite over but a very rare occurrence. So the imperative to maximize existing infrastructure is more urgent, and that is where we think small pools have a huge role to play.”

When it comes to what can realistically be exploited from the 3 Bbbl in small pools across the 300 individual discoveries, Evans said, according to Wood Mackenzie’s analysis late last year, 1.5 Bbbl could be economically exploited.

“First, we considered anything that was within 25 km [16 miles] of infrastructure that had a good economic life ahead of it that was beyond 2022, and we also matched it with hydrocarbon types so an oil discovery close to oil infrastructure,” she explained. “That filtered out a few of the discoveries and we were left with 2.5 billion barrels in small pools to consider.”

Next, the economics of each discovery was examined, using \$50/bbl oil.

“Using these tools and filters we came up with an economic analysis that about 1.5 billion barrels are economic,” she said. “When we added in the benefit of the ‘Tie-back of the Future’ that the OGTC is working on, that showed that the additional impact of that technology had the potential to unlock a further 400 million barrels.”

Working With Industry

Across the OGTC there are other themes that are relevant to this project, such as a late-life and decommissioning project and a well construction operation that is aiming to halve the well costs, facility costs and extend the operating life with lower opex by using automation

and robotics.

The OGTC has only been open a year and has already carried out about \$51.8 million of investment with more than 70 projects across the center. “It’s a very fast pace now,” Pearson said. “We have had very good take up from industry, but with respect to small pools we need more engagement. We need more operators to be engaging with us and sharing their field data and expertise.”

Pearson said that as far as practical deliverables from the project, these would include field development plans coming forward that have no umbilical but have an integrated solution and subsea equipment that is modular and can be reused. “The proof in the pudding is going to be the 400 million barrels that are investable now if we choose to go after them. Between the Oil and Gas Authority ourselves and the government—both Westminster and local—we need to encourage the industry to invest in those opportunities.”

As for how successful operators will be in exploiting small pools, Pearson said it is all about the right assets in the right hands.

“If you have a large portfolio you are going to prioritize it based on your return on capital, the same as any other business,” he said. “Whereas if your portfolio is heavily weighted to some of these small pools, you are going to be forced to go after them to get return on your investment, and then you are going to manage your risk.”

Pearson added, “The industry has a track record. We have delivered fields as small as 3 million barrels and we can relearn that, but [only] with modern technology that allows us to do a lot more in terms of recovery factors. There is a good opportunity here. It’s not pie in the sky; it’s very real and very tangible.”

—Mark Venables

BUSINESS

Aker Solutions Makes Strides With Contract Wins In Brazil

Aker Solutions is working to strengthen its position as an equipment and maintenance supplier in Brazil's deep waters in 2018.

In February the company won a contract to provide maintenance and modification services for three platforms at Petrobras-operated oil and gas fields offshore Brazil. The four-year contract includes an option for a one-year extension.

The order covers a range of services to renovate, repair and upgrade the FPSO units at the Barracuda, Caratinga and Albacora Leste fields in the Campos Basin. It also entails management at the yard where replacement parts and other equipment will be fabricated. The work starts in March 2018 with final deliveries scheduled for first-quarter 2022.

Besides the maintenance contract, Aker Solutions took another step in its business expansion plans in Brazil. In late January 2018, the company successfully installed its first subsea manifold system for Petrobras' presalt Iracema Sul and Lula Norte fields. According to Aker Solutions, this marked one of the company's deepest installations in the world. In fact, the two manifolds that were installed are among eight pieces of equipment for Petrobras in those areas.

The manifolds that were installed help optimize production from platforms through the injection of water and gas to increase the pressure of the wells and, consequently, to increase production from presalt fields.

Reinaldo Mendes, engineering vice president at Aker Solutions Brazil, told *SEN* that four more manifolds will be installed by the end of first-quarter 2018, and more equipment was recently delivered to Petrobras. "It is expected to be installed in the next few days, with the start of flexible line connections through MCVs [well connection modules and platform for water and gas injection] and MTUs [modules of connection with wells and platform for electrical and hydraulic controls]," he said.

For Mendes, Aker's expertise in the North Sea can help to develop subsea activities in Brazil due to the company's experience worldwide. He said this knowledge is being transferred little by little to increase local competencies, and Brazil can play a role in the company's global strategy

for supplying subsea equipment. "The IOCs [international oil companies] investing in Brazil are more interested in a complete subsea solution instead of pieces of equipment."

Mendes pointed to three new contracts Statoil recently signed—Johan Castberg, Troll and Askelkadd—as examples of how the technology employed in the North Sea subsea activities can be adjusted in Brazil's deepwater projects.

"They will be the first three global projects with international operators to be partially executed in Brazil," he said. According to Mendes, those contracts will fulfill the company's strategy of turning Brazil into a global hub, diversifying the portfolio with new international clients and exporting local content. "Aker Solutions Brazil will produce 47 modules of subsea control systems, considering the three projects, in the High Technology Center in the city of São José dos Pinhais, located in the southern state of Paraná."

This brownfield facility, acquired in 2016, is dedicated to machining, welding, surface treatment, assembly and testing of subsea trees and other subsea equipment. It provides subsea control systems manufacturing capability, doubling the company's production capacity in the country. It is part of a global delivery model with subsea execution hubs in the Americas, Asia-Pacific and Europe and will support customers both in and outside of Brazil. Aker Solutions is also upgrading its subsea services unit in Rio das Ostras to better meet customer demand.

The Norwegian company, which has operated in Brazil for more than four decades, is confident about the future of the country's oil and gas segment.

"Aker Solutions is confident with the progressive recovery of the oil and gas industry for the upcoming years. It is still a period of uncertainty and caution, but we are optimistic about the progressive recovery," Mendes said. "The Brazilian potential remains one of the largest in the world. We have technology, competence and capability to face the market. The public policies and the predictability of bid rounds are starting to move forward, but there is still much to be done to attract new investments and make projects economically viable."

—Brunno Braga

Noble Energy Deals GoM In 'Last Major' Portfolio Tweak

Fieldwood Energy LLC will buy Noble Energy Inc.'s Gulf of Mexico (GoM) business and assume other obligations in a deal Noble valued at \$710 million, the company said Feb. 15.

In addition to paying \$480 million cash, Fieldwood will also assume all abandonment obligations tied to the properties, which Noble estimated to be \$230 million.

Noble may also receive a \$100 million payout through 2022 whenever Light Louisiana Sweet oil prices exceed \$63/bbl.

The assets were expected to decline as Noble's focus shifts toward U.S. onshore growth, said Charles Robertson II, an analyst for Cowen.



Fieldwood Energy will purchase Noble's GoM assets in a deal valued at \$710 million, including \$480 million in cash and \$230 million in assumed liabilities.

David L. Stover, Noble's chairman, president and CEO, said the assets have delivered outstanding performance during the past couple of years but no longer fit with the company's portfolio.

"The sale of our Gulf of Mexico business represents the last major step in our portfolio transformation," he said. "This has been done to focus our go-forward efforts on those assets that will rapidly grow our cash flows and margins, primarily the U.S. onshore business and the Eastern Mediterranean."

Since November Noble has divested more than \$2.5 billion worth of assets including its pending GoM deal.

The GoM assets include six producing fields and undeveloped leases. Noble projected GoM net production will average more than 20,000 boe/d in 2018. At the end of 2017, the company estimated its proved GoM reserves at 23 MMboe.

The effective date of the transaction was Jan. 1, with closing anticipated during second-quarter 2018, contingent upon Fieldwood successfully implementing its contemplated restructuring process.

Fieldwood, headed by CEO Matt McCarroll, bills itself as the largest operator on the GoM shelf with interests in about 500 offshore blocks. Most of its assets are in depths of less than 1,000 ft.

Robertson noted that Nobles' Leviathan project offshore Israel, with an estimated 622.9 Bcm (22 Tcf) of gas equivalent in gross recoverable resources is estimated to start production in 2020. The company said in November that the project will generate about \$650 million of net operating cash flow at startup, which it said it has targeted for first sales by the end of 2019.

In the first 10 years of production, Leviathan is expected to generate more than \$5 billion in cash flow, Noble said.

Noble also announced that its board has authorized a \$750 million share repurchase program.

"At today's share price, the program covers about 6% of the company's outstanding shares," Robertson said.

—Darren Barbee

BUSINESS BRIEFS

Tullow Oil Names Kweku Awotwi As New Head Of Ghana Operations

Tullow Oil has chosen electrical engineer and businessman Kweku Awotwi as the new head of its Ghana operations after the retirement of its current managing director, the company said in a statement.

Tullow is lead operator of two oil fields in Ghana including the West African nation's flagship offshore Jubilee reserves, which began commercial production in late 2010.

Awotwi, 57, is the founder of South African-based gold explorer African Precious Minerals Ltd. and principal of Triton Group Ltd.

He was one-time CEO of Ghana's state-run power utility Volta River Authority for more than four years and had previously worked at Ashanti Goldfields as managing director for strategic planning and business development.

Awotwi will start work as Tullow's Ghana operations head on March 1, succeeding Charles Darku, the first Ghanaian managing director who has served the company for five years, Tullow said.

Aside its flagship Jubilee Field, Tullow is also lead operator in the offshore TEN (Tweneboa, Enyenra, Ntomme) reserves, which came onstream in August 2016.

ONGC Acquires 10% Stake In ADNOC's Offshore Oil Concession

A consortium led by India's Oil and Natural Gas Corp. (ONGC) has become the first group to win a stake in Abu Dhabi National Oil Co.'s (ADNOC) 40-year offshore oil concession, a deal set to help the United Arab Emirates expand its foothold in Asia.

State-run ADNOC signed an agreement on Feb. 10 with the ONGC Videsh-led consortium giving the group a 10% stake in the new Lower Zakum offshore concession, with a participation fee of \$600 million, ADNOC said in a statement.

ONGC Videsh is the foreign investment arm of ONGC. Other members of the consortium are Indian Oil Corp. and Bharat Petro Resources Ltd., an upstream arm of refiner Bharat Petroleum Corp.

The contract signing in Abu Dhabi was attended by Abu Dhabi Crown Prince Sheikh Mohammed bin Zayed Al Nahyan and Indian Prime Minister Narendra Modi. It is the first time for Indian oil companies to partake in an Abu Dhabi oil and gas concession.

ADNOC, like other major oil producers, wants to tap rising demand growth and invest in India, the world's third biggest consumer.

Noble Energy's Profit Beats On Higher Sales Volumes, Low Costs

Noble Energy Inc.'s quarterly profit breezed past analysts' estimates as U.S. sales volumes surged and the company kept a tight leash on expenses.

A rise in global crude prices, led by OPEC cuts, has prompted oil and gas companies to ramp up production. U.S. crude prices averaged \$55.30/bbl in the last quarter of 2017, up 12.2% from a year earlier.

Noble's total operating expenses nearly halved to \$740

million in the fourth quarter ended Dec. 31, as exploration costs fell by 90%. Net income attributable was \$494 million (\$1.01 per share), compared with a loss of \$252 million (59 cents per share) a year earlier.

On an adjusted basis, Noble earned 32 cents per share. Analysts on average had expected 4 cents profit, according to Thomson Reuters I/B/E/S.

The Houston-based company's total revenue rose 19% to \$1.2 billion.

—Staff & Reuters Reports

IN MEMORIAM

Former Baker Hughes Chair James D. Woods Dies

Former chairman, president and CEO of Baker Hughes Inc. and noted philanthropist, James D. Woods, 86, passed away in Houston on Feb. 4.

Woods retired from Baker Hughes in 1997, after joining Baker Oil Tools in 1955 and spending his entire career there. He was the guiding force behind the company's 1987 merger with Hughes Tool Co. It was one of the first and largest oilfield service company mergers of that decade. Both companies were more than 100 years old at the time. Baker Hughes has since merged with GE Oil & Gas.

In 2006 Woods was awarded an honorary doctorate of Humane Letters from California State University at Fullerton, where he had graduated with a bachelor's degree in finance. Earlier he had served four years in the U.S. Air Force. He recently provided funding to help build the

new Cal State Fullerton School of Business and Economics, among several other donations he made to the school.

He was also active in Houston affairs, serving through the years as chairman of the Memorial Hermann Health System, YMCA of Greater Houston and as a trustee of Boys and Girls Clubs of America, among many other organizations.

In the oil and gas industry, Woods was a past president of the Petroleum Equipment and Suppliers Association and the National Ocean Industries Association. During his career he served on the boards of Varco International, ITEL Corp., Kroger Corp., Foster Wheeler Corp. and Complete Production Services, among other companies. Upon retiring, he became an adviser to SCF Partners, the Houston private-equity firm that invests in oilfield service companies.

—Leslie Haines

UPCOMING

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