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Project Bringing First FPSO Into Gulf

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HOUSTON–It is full steam ahead on one of the most challenging and innovative projects ever undertaken in the Gulf of Mexico: a two-field development utilizing the Gulf's first floating, production, storage and offloading (FPSO) facility. Moreover, when the FPSO is commissioned in more than 8,500 feet of water in the Walker Ridge area–a world record water depth for an FPSO installation–Cascade and Chinook will become the first discoveries to achieve commercial production in the giant Lower Tertiary trend.

Petrobras is the operator of both Cascade and Chinook, holding a 50 percent in Cascade (Devon Energy Corp. owns the remaining 50 percent) and 66.67 percent in Chinook (with Total E&P owning 33.33 percent).

"This is a big project for Petrobras," states Cesar Palagi, Walker Ridge asset manager for Petrobras America Inc., a wholly owned subsidiary of Brazil-based Petrobras. "This is the first time we have developed a large offshore field outside of Brazil. The deepwater Gulf of Mexico is the place to be, and we are very excited about installing the first FPSO in the Gulf to develop the first Lower Tertiary fields."

The FPSO is being used in the first phase of the Cascade/Chinook development to produce from the reservoirs and assess the fields' potential, and ultimately, a different type of production system may be built depending on reservoir performance and other factors. Phase one is being fast-tracked, according to Palagi, with the schedule calling for completing the FPSO installation in early 2010 followed by first production in mid-2010.

"Bids were let in 2007 for all major contracts of the project," Palagi reports. "That includes not only the FPSO, but also two shuttle vessels that will transport the produced oil from the FPSO, a pipeline that will handle the natural gas, as well as free-standing hybrid risers and all the subsea and production equipment."

The FPSO–to be christened the *BW Pioneer*–will initially accept and process oil and gas production from two subsea wells in Cascade and one subsea well in Chinook (located about 20 miles south of Cascade). Palagi says all three wells were drilled to depths of 27,000-28,000 feet total depth. Based on reservoir performance and the potential to drill more prospects in the eight-block project area, he adds that Petrobras plans to add several more wells in the future.

International Scope

The Cascade/Chinook project is the first major field development executed by Petrobras in the United States, and it is bringing an international scope of partners and contractors together to produce hydrocarbons in the ultradeepwater Gulf. The three operator partners (one the national oil company of Brazil, one a large U.S. independent, and the other headquartered in France) have contracted a Norwegian company, which in turn, is using a British company to help design the FPSO, which is being modified and converted at a shipyard in Singapore before sailing to the Gulf.

Although FPSOs have been used in offshore basins around the world for decades–including offshore Brazil, where Petrobras has 25 years of FPSO experience and has 15 units in operation in Brazilian waters, with nine more under construction–and industry consortia such as DeepStar have done preliminary work to pave the way for an FPSO installation in the Gulf, it took the right project to make it a reality, according to Palagi.

"The main reason we decided to deploy an FPSO is that these fields are some 180 miles south of Louisiana, very remote and far from existing infrastructure," Palagi explains. "The location is almost into Mexican waters. There is no production and no infrastructure in this Walker Ridge area, and building infrastructure is very expensive."

In addition, as the first Lower Tertiary production, there are some unknowns that complicate selecting and sizing a production system design. "There are no analog Lower Tertiary fields in the Gulf to use as a comparison," Palagi points out. "That creates some uncertainty. We do not know how much these fields will produce, so it is difficult to design all the variables into a conventional production facility. The FPSO lets us get these fields on production, while giving us flexibility in selecting a final production system solution."

The U.S. Minerals Management Service granted official approval of the FPSO-based conceptual plan for Cascade/Chinook in December 2006. Palagi says the *BW Pioneer* is crucial to giving Petrobras and its partners the ability to analyze reservoir performance during the early phases of production without committing to full-scale infrastructure development.

"We will see how the reservoirs behave as the fields produce. If the project is as successful as we expect, we will move forward with all phases of the development plan," he details. "We may eventually consider building an oil pipeline in future phases instead of shuttling the production from the FPSO, but given the complexities and costs associated with building production infrastructure and pipelines in 8,000-plus feet of water, a phased development approach is

suitable to deal with the uncertainties of the Gulf Lower Tertiary play, as well as the water depths and the remoteness of the fields."

First Gulf FPSO

According to Palagi, the Gulf's first FPSO at Cascade/Chinook leverages a number of technologies that are new to the Gulf, including:

- A disconnectable turret buoy to allow the FPSO to move off site during severe weather events such as hurricanes;
- Crude transportation using shuttle tankers;
- Free-standing hybrid risers to transport oil and gas from subsea flowlines to the FPSO, and natural gas from the FPSO to a dedicated export pipeline;
- Subsea electric submersible pumps to boost production from the seafloor to the FPSO; and
- Polyester mooring lines for the FPSO.

BW Offshore Ltd. was awarded the contract for converting a tanker into the *BW Pioneer* for the Cascade and Chinook fields, as well as operating the FPSO at Walker Ridge Blocks 249. The $740 million contract is for up to eight years, including optional periods of up to three years after the end of the initial five fixed years. Advanced Production and Loading (APL) is supplying the disconnectable submerged turret production buoy (STP), including a fluid swivel and the mooring system.

BW Pioneer Ltd., an affiliate of BW Offshore, awarded Keppel Shipyard in Singapore a $152 million subcontract for the work to convert the tanker. When completed in the third quarter of 2009, the *BW Pioneer* will be turret-moored at a water depth of 8,530 feet by a polyester mooring system linked to suction pile anchors.

The FPSO will use GPS and onboard thrusters to facilitate the reconnection process, but the entire facility is designed to give the FPSO the ability to disconnect and move under its own propulsion to safe waters in the event of an approaching storm, according to Palagi.

"Disconnectable FPSOs provide a means to improve the protection of life, environment and assets during hurricanes," Palagi says. "That is a big advantage, especially in a region such as the Gulf, which is known for devastating hurricanes."

Tom Arne Kristiansen, director of the BW Offshore's technical division, points out that disconnectable FPSOs are well proven in offshore operations around the world. "We have disconnected FPSOs in the South China Sea 20-30 times for typhoons, and 1,200-1,300 times in the North Sea for storms," he points out. "This is a mature, effective technology that has an unparalleled track record."

There are challenges inherent in disconnecting an FPSO from the riser system and moving off location, however. "The lazy-wave umbilicals are very heavy when connected to the STP buoy," Kristiansen notes. "If we disconnect the umbilicals and they sink to the bottom, they are gone forever. So when we drop the buoy, it requires a lot of buoyancy capacity to keep the umbilicals submerged at the right level (far enough below the surface to avoid damage from high seas and winds). We also have to make sure that everything fits together. It is a big challenge."

Two Main Subsystems

Kristiansen says the STP is made up of two main subsystems: the subsea equipment (turret buoy and moorings) and the shipboard equipment (swivel, connector, locking mechanism, controls, etc.).

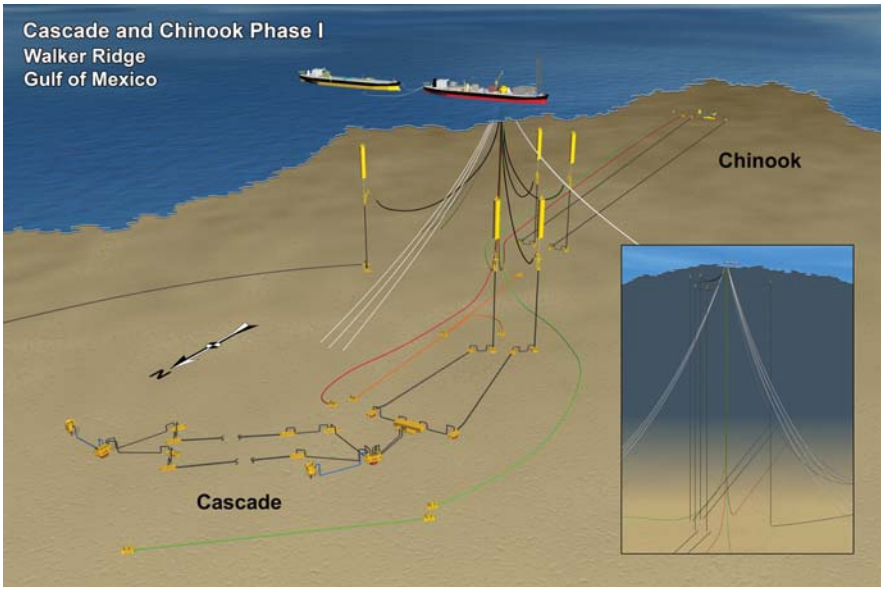
"Part of the requirements for the Cascade/Chinook project is to be able to reconnect the FPSO after it returns to location following a storm without having to mobilize support vessels," he explains. "The STP is designed to make the FPSO the last production facility to shut down when a storm approaches and the first to restart production once it has passed, without having to rely on support vessels or rigs."

The *BW Pioneer* will have a daily processing capacity of 80,000 barrels of oil and export facilities for 16 million cubic feet of natural gas, with a working storage capacity of 600,000 barrels of oil. It also has the capacity to treat and discharge 16,000 barrels of water a day. To power all the onboard equipment, Kristiansen says the FPSO is equipped with three turbines capable of producing a combined 36 megawatts of power.

"There are a lot of technological elements that are part of the FPSO system, and the objective is to deliver a functional system on time to Petrobras and its partners, and hook everything up and have it all work exactly as planned," Kristiansen avers.

While the project is being managed at BW Offshore's office in Oslo, Norway, and the FPSO itself is being converted in Singapore, Kristiansen adds that DPS Ltd. is engineering the process plant in Bristol, England, that will be fitted aboard the FPSO. DPS was awarded a contract for the crude stabilization and flare modules that will form an integral part of BW Offshore's FPSO topsides. DPS will also be responsible for managing the process and piping interfaces for the entire process topsides.

The project is also deploying pipe-in-pipe insulated flowlines on the Chinook Field as part of the first phase, Palagi re-



Petrobras and its partners are installing the Gulf's first FPSO facility to develop the Cascade and Chinook fields in the ultradeepwater Walker Ridge area. The FPSO is scheduled to commence operations in mid-2010, making Cascade and Chinook the first Lower Tertiary discoveries to achieve production. Stationed in more than 8,500 feet of water, the *BW Pioneer* will also set a world water depth record for an FPSO installation.

ports. Petrobras signed a contract with Heerema Marine Contractors to install the Chinook pipe-in-pipe in-field flowlines in water depths ranging from 8,000 to 8,800 feet beginning in spring 2009. "The pipe-in-pipe flowlines are each 12 miles long, with a 14-inch pipe carrying a 9.0-inch inner pipe," he explains.

Subsea Equipment

Thousands of feet below the FPSO in the dark, cold depths of the Gulf of Mexico, subsea wells, manifolds, flowlines and multiphase booster pumps will deliver the oil and gas produced from the Lower Tertiary wells into the onboard processing and export facilities.

Petrobras awarded FMC Technologies Inc. a $200-million contract to supply the subsea systems, according to Steve Barrett, general manager for subsea business (Western Hemisphere) for FMC Technologies. The contract includes four horizontal subsea trees, three manifolds, control systems and horizontal subsea electric submersible pumps to boost production.

"This is an exciting milestone, as the first project in the Lower Tertiary and the first FPSO in the Gulf of Mexico," he says. "From the perspective of the subsea equipment, however, the challenge is primarily related to the integration of the new ESP boosting system and related to the high shut-in pressures. Cascade and Chinook are not our first 15,000-psi subsea completion systems in the Gulf, but the higher pressure rating tends to make the equipment larger and heavier, creating challenges in the overall scalability of the system."

To boost production from the seafloor to the FPSO, the project will use a multiphase pumping system composed of two horizontal ESP boosting stations rather than the centrifugal-type pumps that have been used in other boosting applications in the Gulf, Barrett reports.

"Petrobras conceptualized this ESP-based system and feels very comfortable with it," Barrett continues. "The system fits this application. Configuring and designing the pumps themselves is pretty straightforward. ESP technology is well proven, and for the Cascade/Chinook project, the pumps are merely a new size of a relatively standard product. The rest of the subsea system–the trees, manifolds, jumpers, etc.–are standard designs."

The electric submersible pumps, which are being supplied by Baker Hughes Centrilift, will be housed in retrievable modules on the seabed. "Even though these pumps are designed for long life, you expect pumps to wear out at some point," Barrett says. "They will be positioned on the seafloor in separate containers, with two pumps in each module. Another functionality of this system is that production can bypass the ESP booster pumps."

He adds that the pumps are needed both because of questions about the reservoir's natural pressures and the long distance the produced oil must travel to reach the FPSO. "The delivery of the subsea boosting system is expected to start in the fourth quarter of this year, with a test of the integrated control system taking place in 2009 to make sure all components of the system function as needed," Barrett concludes.

Providing The Power

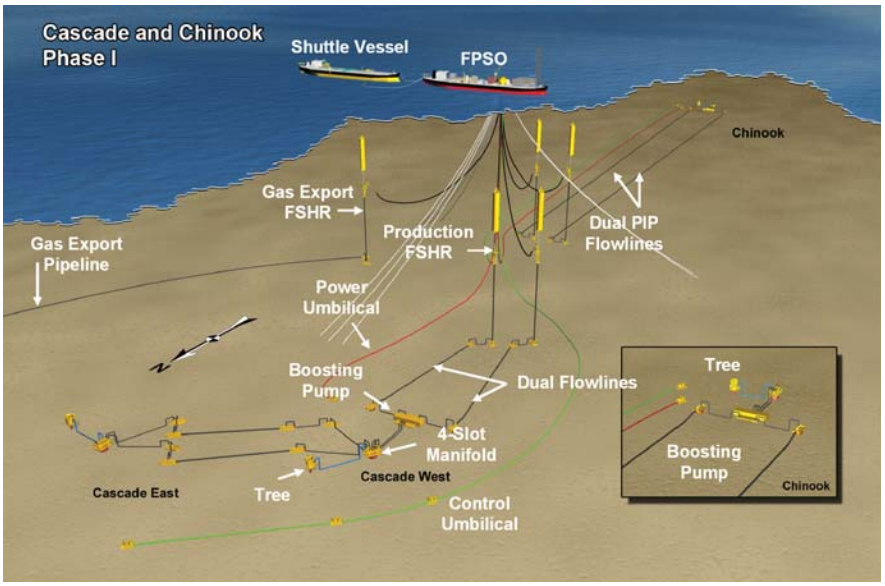
The job of powering the pumps and subsea equipment in such extreme water depths belongs to Aker Kvaerner, which received a $65 million contract to supply subsea high-voltage power cables and production control umbilicals for the Cascade/Chinook project, according to Robert Schriefer, sales manager for umbilicals at Aker Kvaener.

The contract calls for supplying 230,000 feet of high-voltage power cables and static and dynamic steel tube umbilicals. The umbilicals will be made using Aker Kvaerner's patented carbon-fiber rod technology, with project management, engineering and manufacturing conducted at the company's Mobile, Al., facility. The cables and umbilicals are scheduled for delivery in mid-2009.

"Although we are unique in our technical capabilities and solutions, this is one of the more challenging projects we have been involved in," Schriefer remarks. "The unique combination of the water depths, operating off a FPSO and its relative motions, the disconnectable turret-buoy design, and the enormous requirements to power the subsea boosting system all present certain challenges."

A critical requirement for the high-voltage power umbilicals is the ability to withstand the extreme pressures and weight applied by 8,000 feet of water. "We have enhanced the strength of the umbilicals without adding a large amount of weight," Schriefer explains. "To accomplish that, we have incorporated carbon fiber rods into the cross-section of the power umbilicals."

He adds that the umbilical design considers mechanical, thermal and electrical characteristics. "Each power umbilical has nine 150 mm2 power conductors. A key part of the design is to assure that we transmit power with electrical characteristics that align with the requirements of the ESPs," Schriefer continues. "In concert with the



The major components of the Cascade/Chinook early production system include the FPSO, a disconnectable turret buoy to allow the FPSO to move off site during severe weather, free-standing hybrid risers, tankers to shuttle the produced oil to shore-based facilities, a pipeline for transporting the produced natural gas, subsea manifolds and trees, horizontal ESP multiphase booster pumps, pipe-in-pipe in-field flowlines, subsea high-voltage power cables, and carbon fiber-reinforced production control umbilicals.

electrical design, we are also addressing the thermal effects. During operation, the high-voltage power cables will create heat. Our design assures we understand the thermal effects within all components throughout the length of the umbilical. The thermal conditions change as the environmental conditions change. For example, the conditions through the water column are substantially different from that inside the turret buoy or within the I-tube."

In addition to the operational design, Schriefer says installation concerns also are being addressed. "The entire execution plan is included in the design. The carbon fiber rod technology provides Petrobras with an umbilical that is lighter weight and much more installable," he adds. "In conjunction with the crush resistance of Aker Kvaerner's patented PCV profile umbilical design concept, our solution is ideally suited for this application."

Topsides Design

Alliance Engineering, part of the John Wood Group, has been appointed topsides owner's engineer by Petrobras. Alliance will assist Petrobras for up to three years with two scopes of work for the Cascade and Chinook fields, reports Wayne Mueller, Alliance Engineering's leader for Cascade/Chinook.

"One difference in the execution of this project is that we are breaking ground in interpreting and applying U.S. regulations," Mueller explains. "We have plenty of floating platform experience, but there is no precedent here because no one has ever used an FPSO in the U.S. Gulf before. It is considered a tanker when it disconnects, but it is a production facility when it is moored. We have to carefully apply multiple sets of regulatory and industry requirements to both the hull and topsides to ensure compliance. I think it is fitting that BW Offshore has named it the *BW Pioneer* because it is certainly entering new territory."

Alliance will support Petrobras with verification of the topsides design for the FPSO early production system (EPS), with the FPSO expected to be on location for at least five years. In addition, as part of a full-field development scope, Alliance is assisting Petrobras with selecting and planning a final solution to replace the EPS and produce the field over the longer term.

"It is really two different projects," Mueller continues. "Cascade and Chinook are complex reservoirs and the early production system does not begin production until 2010. They cannot predict today how the field will be producing in 2018. No one can declare what the production, pumping and processing needs will be five to seven years from now as the field is developed. No one can declare the optimum answer today."

Mueller says he likens the Cascade/Chinook project to a jigsaw puzzle, where each piece is independent, but must be integrated into the whole in its proper position for the entire system to function properly.

"The FPSO is moored using a disconnectable turret, which is connected to the risers, which are connected to the subsea pumps, which are then connected to the wells and reservoirs," he points out. "It becomes a very big and complex system, but each individual component must fit together with the others. Each company involved in the project has expertise in a given area, but we all have to work together to manage and build the system from the well perforations all the way to the FPSO."

Shuttle Vessels

The final piece of the puzzle is shuttling the produced oil from the *BW Pioneer* to a refinery along the Gulf Coast. On the front, Palagi says Petrobras has signed an agreement with Overseas Shipholding Group to charter two 46,000-ton Jones Act tankers, marking the first U.S.-flagged shuttle tankers to transport oil from ultra-deepwater drilling projects in the Gulf of Mexico (a pipeline to carry the produced natural gas is under construction with a service date of early 2010).

"At expected production rates of 80,000 barrels a day, it may take six or seven days to fill the FPSO's onboard capacity," explains Palagi. "That will give time to offload to the shuttle, and for the shuttle to reach port. Each shuttle will hold about 300,000 barrels, so the shuttles will not have to run 24/7. It is a floating process. After one shuttle is loaded, it will take four days to fill up the FPSO to offload to the second shuttle."

Recent discoveries such as Jack, St. Malo and Stones, in addition to the Cascade and Chinook fields, have generated considerable excitement about the Lower Tertiary's potential. But water depths and well depths make these projects highly challenging, and questions remain about the reservoir's productive capacity, Palagi points out.

"The Cascade and Chinook wells are in 8,000 feet of water, and they were drilled through more than 20,000 feet of sediment. We are basically going as far down beneath the water and into the subsurface as jet planes fly in the skies," Palagi marvels. "It is in the opposite direction, but more than five miles in total distance from the surface of the Gulf to the producing formations."

Eventually, Palagi says Petrobras and its partners hope to expand production from the two subsea wells at Cascade and the one Chinook subsea well that will initially be connected to the FPSO. "The objective of the first phase of the Cascade/Chinook development project is to obtain data and information about the reservoir and well productivity in order to optimize future phases focusing on the number and types of wells, completion design, production system type and capacity, subsea layout and boosting system, and secondary recovery potential," he explains.

"If everything is successful and the project goes as planned, we expect to put up to eight wells from each field on stream," Palagi adds. "We hope to add four wells a year after first production in 2010."

As the first Lower Tertiary discoveries to move to the development and production stages, Palagi acknowledges that the industry will be watching Cascade and Chinook closely to see what the first producing wells indicate about the vast potential of the ultradeepwater Lower Tertiary trend.

"We are fast tracking this project with the goal of putting the fields on stream on budget and on schedule, but we also need the wells to deliver good production performance," Palagi remarks. "These wells will tell us a lot about Lower Tertiary reservoirs, and we will apply what we learn in future work on Cascade/Chinook." ❐