# PERDIDO

## WORLD'S DEEPEST OFFSHORE DRILLING AND PRODUCTION PLATFORM

Supplement to OIL&GAS JOURNAL, OIL&GAS FINANCIAL JOURNAL, Offshore

# Shell
## PERDIDO

CONTENTS




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**VP, PennWell Custom Publishing,**
Roy Markum
roym@pennwell.com

**Managing Editor and Principal Writer**
Richard Cunningham
Richard@RCunninghamStudio.com

**Technical Writers,**
Jerry Greenberg
jerrygreenberg@earthlink.net

Pramod Kulkarni
pramodk@aol.com

F. Jay Schempf
fschempf@sbcglobal.net

**Contributing Photographers**
Travis Benson
Travis.Benson@Shell.com

Mike Duhon
mike.duhon@yahoo.com

**Presentation Editor/Designer,**
Chad Wimmer
chadw@pennwell.com

**Production Manager,**
Dorothy Davis
dorothyd@pennwell.com
918.831.9537
fax: 918.831.9415

**Circulation Manager,**
Tommie Grigg
tommieg@pennwell.com
918.832.9207
fax: 918.831.9722

**PennWell Petroleum Group**
1455 West Loop South, Suite 400
Houston, TX 77027 U.S.A.
713.621.9720 • fax: 713.963.6285

**PennWell Corporate Headquarters**
1421 S. Sheridan Rd., Tulsa, OK 74112
P.C. Lauinger, 1900–1988
Chairman, Frank T. Lauinger
President/CEO, Robert F. Biolchini

"We are building on a Shell's long history of successful deepwater projects. That combination of experience and ability has allowed us to take this next big step."

**Joe Leone**

Vice President, Developing Assets

"The second deepest drilling and production platform in the world is in 6,300 feet of water. The idea of bringing full functionality to waters nearly 8,000 feet deep and 200 miles from the onshore base is a big step for the industry."

**Dale Snyder**

Perdido Project Manager

"Perdido demonstrates Shell's ability to combine creativity and technology to safely push back deepwater boundaries. This development paves the way for going beyond water depths of 10,000 feet."

**Bill Townsley**

Perdido Venture Manager

1000 ft
2000 ft
3000 ft
4000 ft
5000 ft
6000 ft
7000 ft
Deepest spar in the world / Deepest drilling and production facility in the world
8000 ft
9000 ft
Deepest producing subsea well
10,000 ft

# STRATEGIC DEVELOPMENT ON THE OUTER EDGE

When Shell acquired the ultra-deepwater leases for Perdido in 1996, the technology to develop them didn't exist. There were other notable deepwater developments, of course. Each had pushed the boundaries of technology, but in solving Perdido's many technical challenges, Shell has opened new frontiers for oil and gas exploration.

The Perdido oil and gas development covers a portion of the geological formation known as the Perdido Fold Belt. The producing reservoirs lie within the Paleogene or Lower Tertiary zone, a portion of the Gulf of Mexico that has not been produced before. The seabed there resembles a small version of the Grand Canyon, including cliffs with near vertical drops of up to 1,000 feet.

The hub of the Perdido development is some 200 miles due south of Freeport Texas. The nearest neighbor is the Hoover-Diana platform, about 60 miles to the north. Shell began 3D seismic surveys on Perdido in 1998. The discovery well was completed in 2002. Development drilling began in 2007 and is scheduled to continue through 2016.

"There is a lot of courage in this story," says Bill Townsley, Perdido venture manager. "We purchased the Perdido leases in up to 10,000 feet of water at a time when the industry's capability was barely 3,000 feet. One of our satellite wellheads will be installed at 9,627 feet."

**A WORKABLE PLAN**

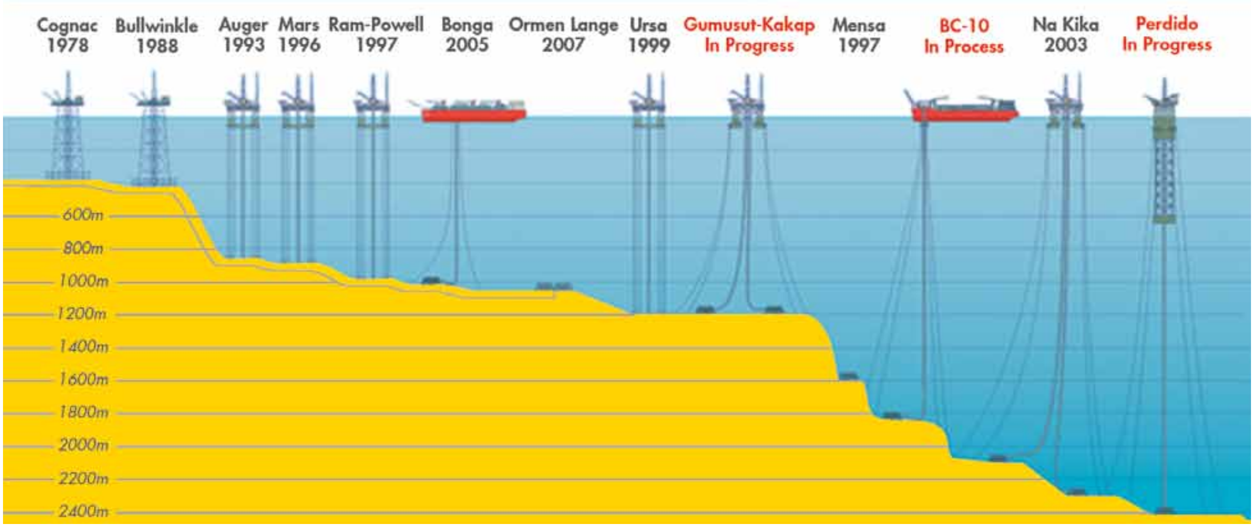
"I joined the project in January of 2005," says Dale Snyder, Perdido project manager. "By the end of the year, we'd settled on a development concept and begun the front-end engineering and design."

Safety, cost and functionality were the project team's primary concerns. A large tension-leg platform – common on other deepwater developments – wouldn't work at Perdido because of the extreme water depths. Whatever floats on the surface has to support the weight of everything below, so in Perdido's case, just the weight of the mooring lines, risers and other equipment hanging from the platform would be overwhelming.

Engineers also had to design for the higher crushing pressures of depths greater than 9,000 feet, and other environmental forces such as storm-driven waves, hurricane-force winds and the Gulf of Mexico's strong loop currents.

"The deeper you go, the bigger these structures

**Dale Snyder,** Perdido project manager




get – unless you break the pattern," Snyder says. "For Perdido, we also have reservoirs that are atypical for the Gulf of Mexico. Because of low reservoir pressures and the variety of our target zones, Perdido requires a lot of wells."

There are up to 35 wells in the Perdido development plan. Twenty-two are directly under the spar. A conventional deepwater production system would require 22 risers with all their associated bulk and weight.

"Economically, we just couldn't make that work," Snyder says. "It is very expensive to solve the technical problems and operate things at extreme water depths. Beyond that, if you build a mammoth structure, the cost of construction becomes prohibitive. For Perdido, we wanted a new kind of deepwater platform, one that was light enough to be economical, yet big and sturdy enough to contain all the drilling and production equipment we needed to develop the field."


Photo provided by Noble Corporation

The Perdido concept design team wanted a central platform with full drilling and production capability onboard. Before Perdido, the world's deepest water depth for such a platform was 6,300 feet, but several emerging technologies, including direct vertical access to the wells (DVA) and a subsea boosting system allowed the engineering and design team to greatly reduce the size of the structure.

"We needed to be able to pump liquids from the seabed to the surface," Snyder explains. "In shallower waters, that's not a big issue, but when the water is a mile and a half deep, it takes a lot of pressure to move fluids up to the platform. Most new reservoirs have enough internal pressure to overcome the hydrostatic pressure above them and push fluids up the wellbore to the surface. Perdido's reservoirs are relatively low pressure, so we needed a boosting system."

The other significant challenge was the potential of forming hydrates – an icy mix of water and natural gas that can easily clog flowlines. The solution was to separate gas and liquids on the seabed, then let the subsea boosting system push them to the surface, each through different lines.

With that capability, the design team could comingle fluids from all the wells on the seafloor, before pumping it to the surface. It was part of the enabling technology. Instead of 22 production risers from 22 wells, they only needed five, and with just five risers, Perdido could be a much smaller platform.

## TARGET ZERO

From the beginning, the safety of the workforce was a critical design element for the engineering team. No project managers want to have injuries on the job, but the remoteness of the Perdido development presented some unique challenges.

"We started off in 2005 with the idea that Safety was the most important thing we would do on Perdido," Snyder recalls. "We would get it right. We would be a world leader in safety, and we put tremendous effort into that."

The design team named their safety program "Target Zero." The core concept was that if you could convince someone to work safely for just one shift, then it was possible to do the entire project that way. In mid-November, 2009, Perdido reached the milestone of 10 million man hours without a lost-time injury. Even with the wide range of complex operations, high-risk activities and fabrication sites around the world, by the time Perdido reached first oil on March 31, 2010, there were still no known lost-time incidents.

"Of all our accomplishments," Snyder says, "I am most proud of our safety performance. It shows the leadership and commitment of our teams to go after safety and make it the most important thing we do."


## A NEW FRONTIER

The Perdido project is remarkable for its own technical achievements, but there is an even wider significance for the petroleum industry. The Paleogene-era rock that Perdido is tapping is older and deeper that other producing formations that have made the region so prolific. Other operators in the gulf have also made recent discoveries in the Lower Tertiary, but Shell is the first to develop it.

As Perdido's decision executive during the critical offshore installation phase, **Lisa Johnson** was responsible for integrated project delivery.

"This is a whole new regime for the Gulf of Mexico," Snyder says. "Not only have we paved the way by solving the biggest problems of an ultra-deepwater development, it is equally important that we've figured out how to produce from the Lower Tertiary. The whole industry is watching to see how we do, because many development companies see this as the next big opportunity."

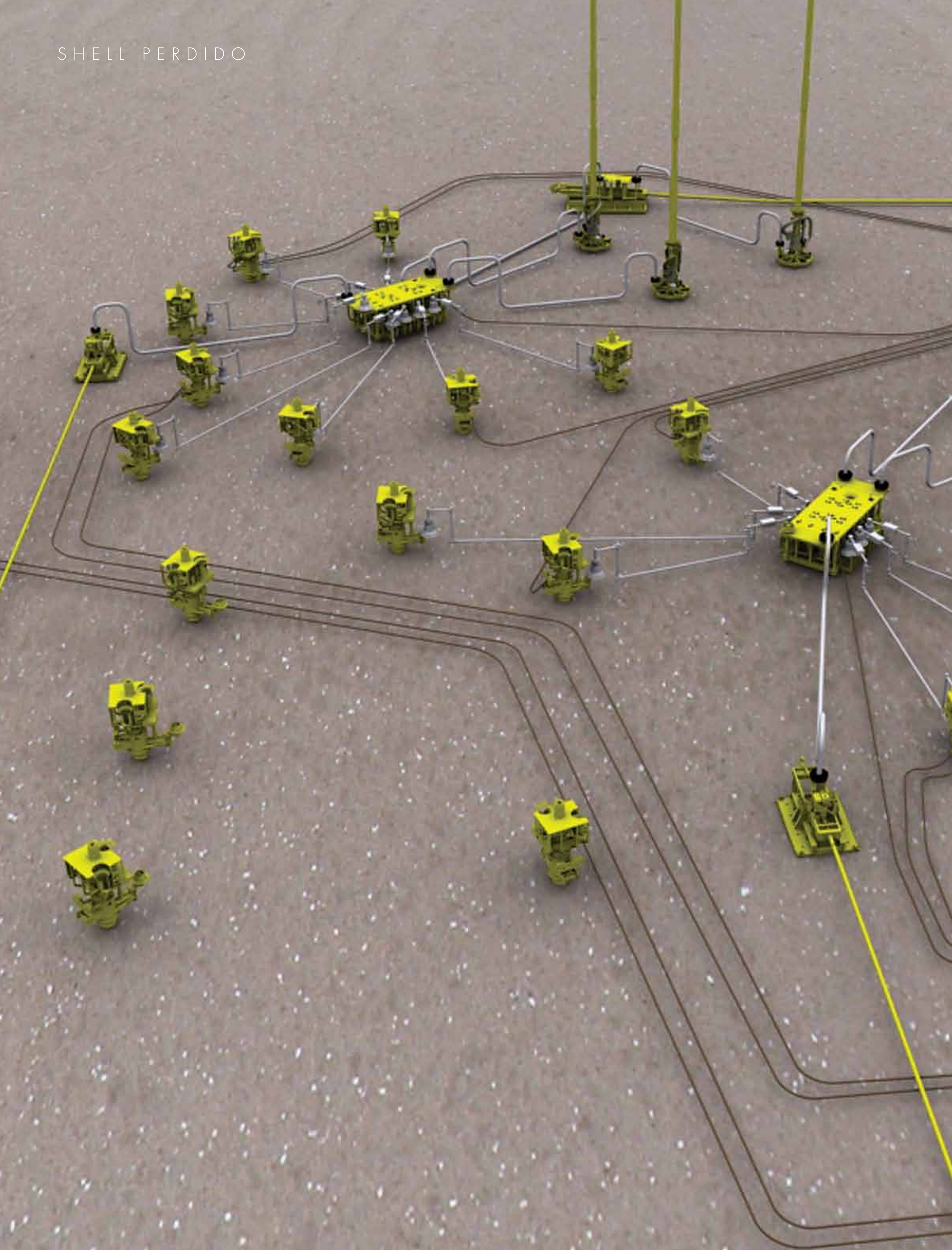
"While the project had its share of inevitable setbacks, the team's response was outstanding, says Lisa Johnson, who was the decision executive during offshore instllation. "There was always a healthy balance of support and challenge throughout the team, as well as with our Perdido partners."

Particularly effective was an all-team meeting with the Perdido contractors. Held early in the project, it allowed everyone involved to review various aspects of their work and to identify any significant conflicts.

## BUILDING ON A STRONG PARTNERSHIP

"I've dealt with a lot of partnerships in my career," says Bill Townsley, Perdido Development venture manager. "The deepwater environment is no place to be arrogant about your skills. We have two experienced partners on this project, so one of the things we've done is to be very open and transparent with our design and planning. The cooperation between partners has helped to keep us on track and deliver this project on time."

**Bill Townsley,** Perdido Development venture manager



# THE SUBSEA SYSTEM

Two related technologies make the subsea portion of the Perdido project viable: the subsea boosting system, and a surface blowout preventer for drilling and completing the direct vertical access subsea wells. A total of 22 wells will be drilled from the Perdido spar and another 13 will be offset wells with tiebacks to the host platform.

The final development plan may seem like an obvious solution now, but there were many questions early on, and some of the technology is being used for the first time. G. T. Ju, Subsea Team lead, joined the Perdido project at the beginning of 2003, almost immediately after results came in from the discovery well.

"Very early in the project we recognized that with these water depths, low reservoir temperature and pressure, and the huge uncertainty of the reservoir's deliverability, that if the project were to go forward, we had to minimize the risk," Ju says. "We needed some sort of subsea boosting or artificial lift technology to put energy into the flow system."

The team's next decision was which technology to use. Was it best to put electric submersible pumps (ESPs) in the wells, or better to use multiphase pumps on the riser base to move all the fluids and gas to the surface?

The Perdido development consists of three main oil-bearing reservoirs, each with distinctly different fluid properties. The oil ranges from moderately heavy to light, with gravities from 17 to 40 degrees API. Gas volumes at the mud line are quite large, so multiphase pumps would be too inefficient to consider. Typical gas/oil ratios (GORs) at Perdido range from 500 scf to 2,000 scf per barrel of oil. Even if multiphase pumps could be used initially, they would become less efficient or cease to function altogether as the GORs changed over time. Electric submersible pumps in the wellbore were also ruled out, because of the huge cost of replacing them in the future.

Ju's team settled on a third option, one that had never been tried before: subsea separators, plus subsea boosting pumps to get liquids to the surface.

"We're using a two-phase separation system on the seabed, flowing gas to the surface and pumping only the liquids," Ju says. "That gives us two advantages. One is energy efficiency, but it also extends the lives of the pumps. If the equipment is just moving liquid, it is much better than pumping a mix of liquids and gas."

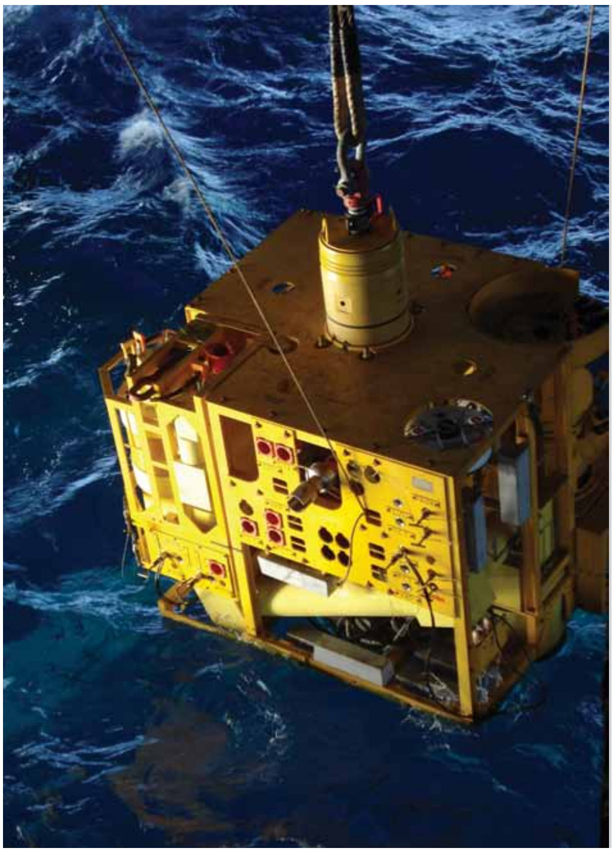
The second advantage to a two-phase system is that it

**G. T. Ju,** Subsea Team lead

takes out the subsurface uncertainty. "This is a new reservoir," Ju says. "There is no producing analog to tell us how the gas/oil ratio is likely to change over time. By separating gas from the rest of the produced fluids on the seabed, we don't have to worry about the potential changes over the life of the reservoir, or the differences between our three main reservoirs. Subsea boosting, with two-phase separation and single-phase pumping became our obvious choice."

## HARDWARE ON THE SEABED

The core of Perdido's subsea boosting system (SBS) is a cluster of five vertical gas-liquid cylindrical cyclonic (GLCC) separators. The body of each separator is a heavy pipe, 35 inches in diameter and 350 feet long. Production from all of the wells comingles in these vessels. The primary function of the caissons is to provide a surge volume for the separated production liquids. The passive system relies on centrifugal force to separate gas and liquids as they swirl down the outer walls of the caisson.



All but the uppermost portion of the separator is inserted into the seabed. A 1,600-horsepower electric submersible pump (ESP) is deployed inside, near the bottom of the vertical caisson.

At the top of the separator, just above the mud line, sits a 2-story tall inlet assembly. Above that, a 17-foot-long reducer brings the diameter of the pipe down to 14 inches, matching the diameter of the riser. From there, the riser extends some 7,800 feet to the Perdido spar.

Each caisson's inlet assembly connects to the host through a top-tensioned riser that contains three separate flow paths. The outer annulus of the riser carries the relatively dry gas. The middle annulus carries produced liquids, which are pushed to the surface by the power of the ESP at the bottom of the separator caisson, and a small diameter pipe in the center carries liquid sent down from the surface to prime and cool the submersible pump. The 14-inch riser allows direct vertical access to the boosting pump at the bottom of the caisson.

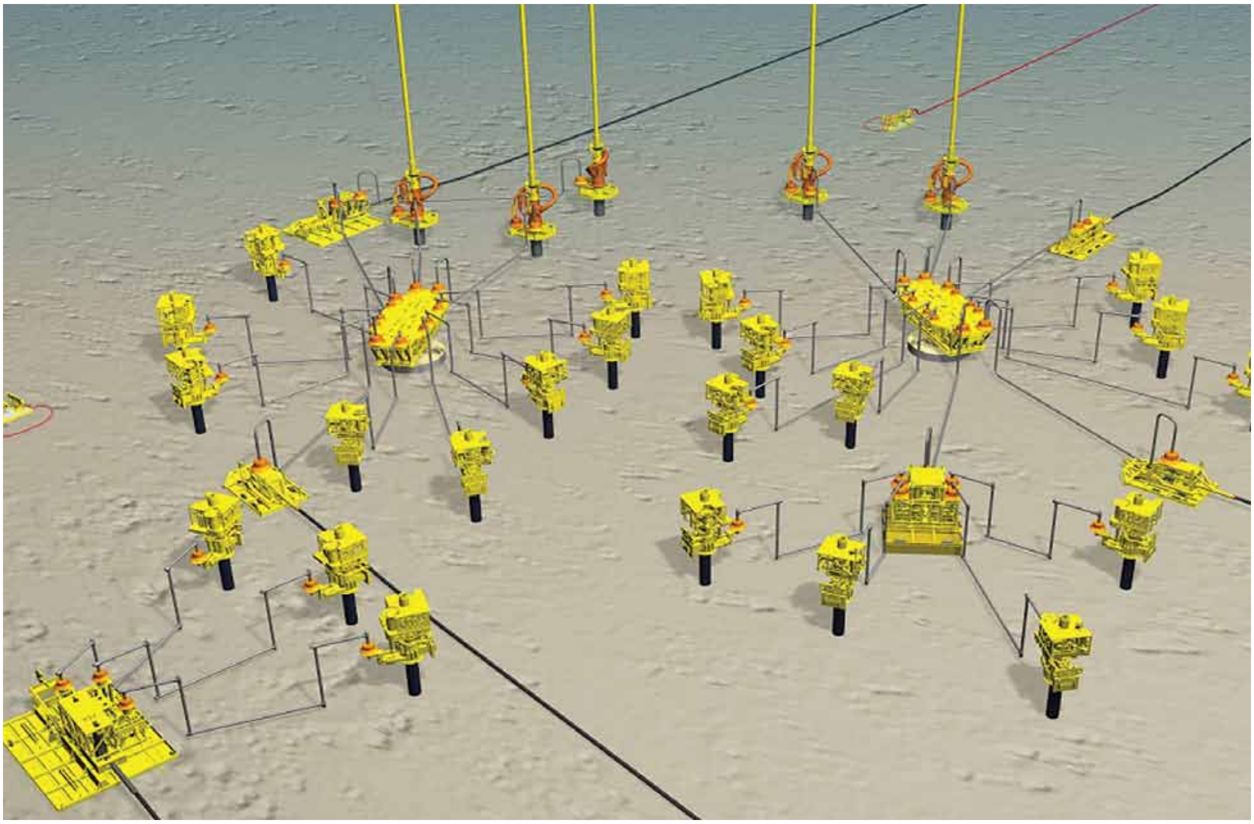
## SUBSEA TREES AND MANIFOLDS

With the water depth at Perdido approaching 10,000 feet, using Shell's existing first generation standard tree system was not an option, since it is designed for water no deeper than 7,500 feet. In planning Perdido's subsea trees, the team also wanted to update the seals, actuators, materials and connectors, and to be able to accommodate a wider range of deployment and intervention options.

The new standard tree system they developed incorporates Shell's experience with previous deepwater installations as well as some recent innovations. The new system is rated for 10,000 psi and 10,000 feet of water depth. It has a retrievable flow module that contains both a multiphase flow meter and a choke. The tree's modular design allows it to be configured for the requirements of the field, and its compact, lightweight components make it easier to service and deploy than previous systems.

Shell's ultra-deepwater trees are rated for 10,000 psi and 10,000 ft of water depth.

Load-out of the subsea manifolds



Subsea layout below the Perdido spar

All of Perdido's wells are being drilled either from the spar itself, or from moored or dynamically-positioned floaters with single or dual derrick systems. That difference in drilling systems led to some variety in the way the subsea trees were installed.

## THE SURFACE BOP

The idea of using wet-tree wells with direct vertical access from the spar helped minimize the size of the host platform. All of the drilling, completion and subsequent maintenance of the spar's 22 wells can be completed using the onboard rig. The rig is held in a fixed position over a well by adjusting the mooring lines on the spar. Tension on the mooring lines can be adjusted to reposition the rig over a different slot.

This system is significantly less expensive than using a 5th generation floating rig to complete and service the wells.

Perdido's onboard capability includes a custom wellhead, riser and blowout preventer (BOP) system. The surface BOP is a custom made 16-¾-inch unit with a rating of 5,000 psi. It is connected to a top-tensioned, high pressure drilling and completion riser (DCR), which was also designed specifically for the Perdido project.

"Unlike surface BOP operations from floaters, no subsea isolation device is needed on the bottom of the riser, because the spar's rig is considered to be a permanently moored structure," Ju says. "The DCR is designed to stay connected if the rig has to be abandoned for a hurricane."

For most drilling and completion activities, well operations are similar to dry-tree DVA wells. The most significant challenge in completing subsea wells with a surface BOP is running and landing the subsea tubing hanger with a subsea isolation device.

"We had to address three main issues," Ju says. "First, the umbilical lines required double terminations if a surface spanner joint was used. Second, we needed a way to pressurize the annulus for testing, and third, we needed to reduce the size and weight of the conventional installation and work-over control systems (IWOCS) umbilical for this water depth."

The Perdido solution is a hybrid configuration in which the IWOCS umbilical is replaced by two six-line flat packs for the hydraulic functions, and a single line for the electrical connection. The lines are run with the landing string, just as the control lines are run with the production tubing, so it is not necessary to have a surface spanner.

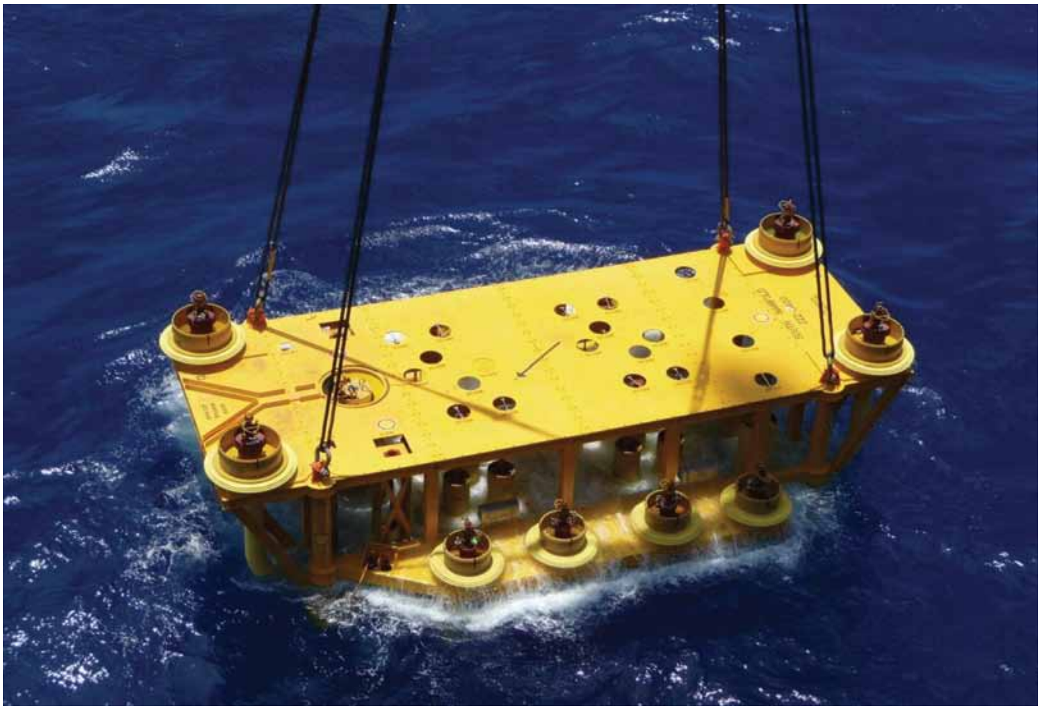
Installing an inlet assembly

## MATURING THE TECHNOLOGY

Ju's subsea team had a lot of confidence that their system would work, but the fact was, no one had tried it before.

"It was a major challenge," Ju recalls. "We had to show senior management across three major oil companies, Shell, BP and Chevron, that the whole investment could hinge on the success of this technology. At this very early phase, when we really didn't have a project yet, we were asking for

Subsea manifold



Installing a subsea manifold

several million dollars to mature the technology and convince managers that subsea boosting and separation would work."

With a test budget approved, the subsea team devised a technology maturation process to prove that the system could function in 8,000 feet of water. A pilot test at that water depth was out of the question, so the team did the next best thing.

"We convinced the venture that subsea boosting and caissons with ESPs would be a good thing to do," Ju says. "And to demonstrate the system, we built a flow loop at Shell's Gasmer research facility in Houston."

"At the Gasmer facility, we built a full scale flow loop of everything that would be below the inlet assembly head," Ju says. "We could generate 55 million scf of nitrogen and pump 30,000 barrels of mineral oil through a system to simulate the concept."

That allowed the subsea team to see how the separator caisson worked, how the controls worked and if the system was efficient. The Gasmer facility was used extensively for more than a year. Practice sessions taught operators how to run the system and how to start the electric submersible pump using additional fluid from the spar. The testing, which was completed in 2007, gave Ju's team and managers of the JV partners the confidence to invest in the new technology, even without a pilot installation in the field.

"With the integration of wet-tree DVA and subsea boosting, we were able to reduce the diameter of the spar from 180 feet down to 118 feet," Ju says. "That directly affected the cost of the spar and the weight of the topsides. Not only were we able to mitigate the subsurface risk, we reduced the total project cost. We took some risk with new technology, but in reality, subsea boosting and separation was the enabler that allowed us to do this project."

## INSTALLING THE SBS

The subsea team grew to 60 people during 2008 and 2009, the peak of the installation phase. The effort – concentrated around the Perdido hub – required lots of coordination.

"We had to work between two major activities," Ju explains. "One was the installation of the spar, because some or our equipment had to go in first. The other major activity that competed with our portion of the installation was the topsides, because we could not complete the subsea work until the topsides was in place. That made the subsea installation a two-stage process."

## FLOW ASSURANCE

The inherent challenges of Perdido, including the extreme water depth, low reservoir energy and challenging project economics, meant that flow assurance was critical. To understand the potential problems, the subsea team analyzed well fluid samples and conducted thermal-hydraulic studies at the onset of the project feasibility assessment. That allowed key flow-assurance considerations to be incorporated into the appraisal well campaign, then carried over into concept selection and project execution.

## WORKING IN A HOT MARKET

The Perdido development was sanctioned at the end of 2006. Soon after, the oil and gas market picked up and it became difficult to get equipment and to find skilled people to work on the project.

"Quality was a major issue," Ju says. "Everybody in the industry was rushing. It was hard to get products delivered on time."

Subsea tree

That became an increasing challenge during 2007 and 2008.

"We were scheduling everything around two major activities. In an overheated market, you need to deliver in time, otherwise you miss the installation window. We constantly juggled the installation schedule. Nothing could happen too early or too late. We had to manage the whole vendor community to deliver our equipment in time, and that became quite an art."

Unlike the spar construction, the Subsea team served as the general contractor for the project manager. As such, the team itself managed its portion of the project and issued more than 100 purchase orders to different vendors. The largest of the purchase orders went to FMC, which provided the trees, manifolds, tie-in kits and some of the subsea boosting equipment. Heerema installed the flowlines and manifold, and many smaller vendors provided other equipment and things such as chemicals and services during commissioning.

"The team effort it took to deliver such a challenging project in that kind of tight market condition was amazing," Ju says. "We also had a great relationship with Chevron and BP. Although the JV partners were not required to contribute directly to the design and fabrication, installation or commissioning of the subsea equipment, they were very supportive. They came to our subsea team meetings and offered their candid opinions. It has been a constructive relationship and a very friendly working environment."

## CONTINUOUS FOCUS ON SAFETY

Everyone who has been associated with Perdido comments on the lasting culture of safety it has fostered. Those who have been with the project the longest add that the continuity of the personnel – some who were involved from the discovery well through final commissioning – has also contributed to the project's success.

"I've had people who have been with me for six years," Ju says, "and I have been with the project for more than seven years. Our project manager, Dale Snyder, set an almost impossible safety goal, but through the entire subsea construction and commissioning we had only one recordable incident. That kind of performance is impressive."

# BUILDING THE WORLD'S DEEPEST DRILLING AND PRODUCTION PLATFORM

Shell has more than 30 years of success in the design, fabrication, installation and operation of the world's most advanced deepwater systems. Perdido is Shell's first spar host drilling and production platform – a system selected because of the extreme water depths, the nature of the reservoirs and remoteness of the field.

Technip was announced as the spar and mooring contractor in April 2006 and began working on a detailed design in June. An engineering, procurement and construction (EPC) contract was awarded to Technip USA in November 2006 for the design, fabrication and dry transport of the spar and mooring system for the Perdido development.

For efficiency in building the overall team, the spar and mooring leads for Shell shared office space with Technip's project management, with integrated teams working at both companies' offices in Houston, Texas. The spar fabrication site team was based at Technip's fabrication yard in Pori, Finland. Senior managers from both companies attended an alignment workshop in October 2006, and subsequent team-building sessions in Finland and Houston helped establish an excellent working relationship from the start.

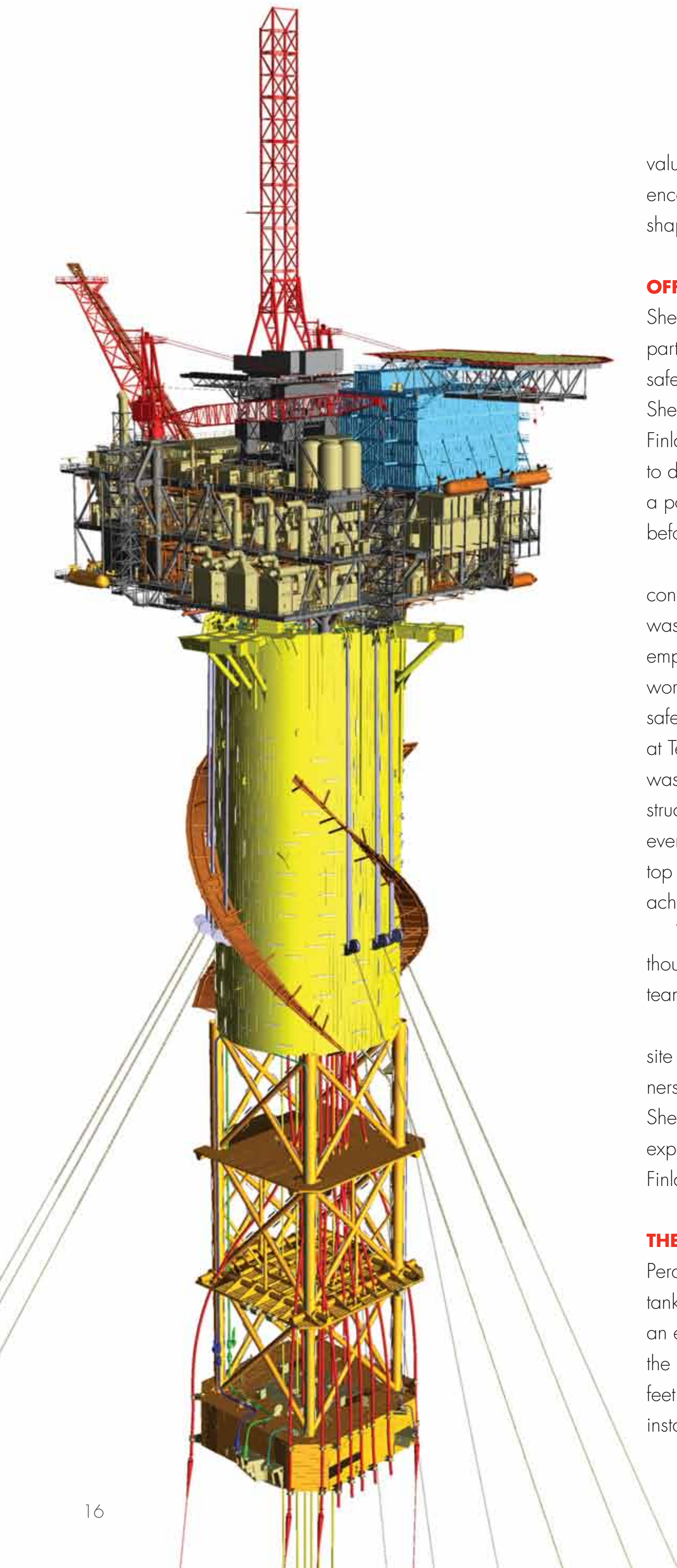
Heerema Marine Contractors (HMC) was named in the spring of 2006 as the primary transportation and installation contractor. It was a critical step, because the finished spar and topsides would have to be designed to fit the capacities of the available transport and installation vessels. To complete Perdido, Shell needed two of the largest installation vessels in the world: Hereema's Balder for the spar and Thialf for lifting and setting the single-lift topsides. Hereema's project team, based in Leiden, The Netherlands, worked directly with Shell's transportation and installation team in Houston.

"On the construction side, we selected Technip based in part on its previous experience building spars," says Curtis Lohr, project manager for the Perdido spar and mooring system. "That saved considerable time and expense on the front end, because we were able to use Shell's extensive deepwater project experience to build on Technip's previous spar experience."

Perdido was Technip's 1- spar project. When fabrication began, the same Technip yard was completing another spar for one of Shell's partners on Perdido.

"We chose a design similar to what Technip had built before," Lohr says. "We made modifications, of course, but part of my job was to balance which of those changes added

**Curtis Lohr,** Spar and Mooring System lead



value to the project and which of them were just preferences. It was also very helpful to see another spar taking shape in the yard."

## OFF TO A GOOD START

Shell team leads began working with their Technip counterparts early on to establish goals for project execution and safety. Eight months before the EPC contract was awarded, Shell and Technip held their first team-building meeting in Finland, then met there again four months later. The effort to develop working relationships at the site continued when a portion of Shell's site team moved to Finland two months before the contract was awarded.

Senior managers went to Finland one month before the contract was awarded, again to make sure that everyone was aligned on safely delivering the project goals. Shell employed a larger site team than Technip had traditionally worked with, including a significant team of inspectors and safety coaches. The continual presence of the safety coaches at Technip's yard helped ensure that the priority on safety was maintained while delivering on the challenging construction schedule. This proactive approach included safety events and demonstrations to reinforce that safety was the top priority and that "goal zero – one shift at a time" was achievable.

The Shell site team at Technip grew to 14 members. Although that's small by Shell standards, it was the largest client team that Technip had ever seen.

"The key was convincing Technip that we were not on site to police the work," Lohr recalls. "We were there as partners working toward common goals. We brought the best Shell had to offer in terms of our construction and deepwater experience, and I think that the team, working together in Finland and in Houston, delivered a superior product."

## THE SPAR

Perdido's spar includes a cylindrical upper section (the hard tank), a trussed midsection of tubular legs and braces, and an enclosed octagonal bottom section (soft tank) to contain the fixed ballast. The outer diameter of the hard tank is 118 feet (36 meters), which is small enough to allow offshore installation of the topsides by the *Thialf*, yet large enough to

provide the required buoyancy and to contain the platform's various liquid storage tanks.

The spar is 555 feet (169 meters) tall, with a draft of 505 feet (154 meters) and gross weight of 20,000 tons (18,143 tonnes). Strakes around the circumference of the hard tank are standard equipment on deepwater spars. Strakes help keep the platform from oscillating by disrupting the flow of ocean currents around the spar.

## HANDS-ON MANAGEMENT IN FINLAND

"One of my goals was to meet everybody who worked on the spar," says Paul Dixon, who was part of the spar, mooring and riser design effort since 2003, and moved to Finland in 2006 to oversee construction of the spar. Dixon even learned to speak the Finnish language.

"There were about 1,700 people at the yard every day and I met as many of them as I could," he says. "I wanted to talk to people and make sure they knew me. I wasn't critical of their work, I just wanted them to know that I did not want to meet their families for the wrong reasons."

One of the biggest challenges in building the spar was a delay in the project ahead of Perdido. The oil market was booming, so every shipyard was busy. A huge new power plant was also under construction just 60 miles south of the Technip yard, so skilled workers were hard to find.

Welders cut the first piece of steel on November 1, 2006, right on schedule, but in January Technip managers told Shell that they needed to take some of the engineers and fabrication people off the project for a while so they could finish the otherspar in the yard. The loss of the engineering staff was especially bad news, because their work has to be done before procurement and fabrication. Any delays were critical, since offshore transport and installation vessels are scheduled more than a year in advance.

"Even though fabrication started on time, the manpower needed was reduced," Dixon says. "Technip employed a local engineering company that it had worked with before and knew the process. Technip also brought a crew of 40 fabricators from Poland to the yard."

The extra engineering staff and the fabrication crew helped make up for lost time in the yard, but it was difficult to keep up. To avoid any safety issues caused by a difference in language, the Polish crew worked on specific areas of the spar in a separate portion of Technip's yard but using the same HSE management plan.

**Paul Dixon,** senior staff engineer, oversaw construction of the Perdido spar in Finland.

"That actually worked to our advantage," Dixon says. "The Polish workers were good, so we'd tell the Technip guys, 'Look how clean their area is.' Later, we'd go to the Polish workers and say, 'Look how well the Finnish workers are doing.' Everyone knew we were teasing, but it helped to set up some friendly competition."

## SAFETY IN THE FAST LANE

Of all the Shell-sponsored safety promotions at the Technip yard, one stood out. It was the day that the popular Finnish race car driver, Kimi Räikkönen came to visit.

Formula 1 race car driver Kimi Räikkönen

"First thoughts of the event were in October 2006 and we worked until August of 2007 to make this happen," Dixon says. "At the time of Kimi's visit, he was three wins away from winning the 2007 world championship in Formula 1."

Räikkönen, who was driving that season for Ferrari and sponsored by Shell, is a national hero in Finland. Dixon knew he would draw a big crowd.

Dixon wanted something special, so he met with Räikkönen before the event and spoke about it not being about Technip or Shell or Ferrari that day. "On that day, I wanted him to talk to the people of Finland about safety. They love him. They respect him. I knew they would listen."

Dixon asked the racer to talk about his job, how he prepares for a race, his personal safety gear and the safety features of his car. "I asked him to show the people how much he focuses on safety. I wanted the people to see that it's the same thing we do here."

That inspirational message, coming from such a respected figure, captured everyone's attention. About 1,200 attended the event, and most went home thinking not just about safety on the job, but also safety in their personal lives and the lives of those around them.

"If there was a special achievement in that event, that was it, Dixon says. "I think we had a lot of fun and changed a lot of lives that day."

## A CONTINUING JOBSITE PRESENCE

Shell's 14-member spar fabrication team let people know they were interested in the work. At least once a week, two site team members would visit on one of the three shifts. Their primary role was to show Shell's presence in the Technip yard. Observations were written down after each tour.

"That was when those of us on the site team really got to know each other well," Dixon says. "The third shift was the hardest. It was from 11:00 p.m. to 7:00 a.m. These were different hours than the site team would typically work and we would go in pairs to watch out for one another. We didn't want to ignore the night shift and all the hard work being performed."

In April 2007, large individual segments of the spar were being assembled, and it started to look like a spar. By then, workers had logged some half-million safe hours on the job. One worker was injured, resulting in the first recordable . The contractor was not sure what Shell's initial response to the recordable incident would be, but Dixon decided it was time to celebrate the project's good safety results to date. T-shirts were printed and Shell provided meals for all three shifts. Site team members greeted workers and thanked them for the 500,000 safe hours so far, and encouraged them to try for 1 million.

Between management, engineering and fabrication, the total workforce reached about 1,700 people at more than a dozen sites throughout Finland. Site team members visited them all. One major fabricator was 8 hours away from the site team's base in Pori.


Regular site team visits helped keep the focus on safety.


DOCKWISE

Managers from the various subcontractors also visited the Technip yard.

"We had a Contractor Day early on," Dixon says. "We took them all around the Technip yard to show them what we were doing, how we were doing it and why. Then we listened to what the subcontractors were doing well and why. It was the first time that had been done, and I believe that it contributed to the project's outstanding safety record. The Perdido development has logged more than 10 million man hours without a lost-time incident. About a quarter of it came from the spar fabrication site, and I'm very proud of that."

### SAIL-AWAY

Fabrication at the Technip yard continued from November 2006 until May 2008. After more than 2.3 million man hours of work without a lost-time incident, the spar was skidded aboard the semi-submersible *Dockwise Mighty Servant 1* in Pori, Finland on May 27 for the 8,200-mile (13,200-kilometer) dry transport to Kiewit Offshore Services in Ingleside, Texas.

"That was an emotional day," Dixon says. "Watching the spar sail away was like watching your child go off to college."

The spar arrived at Kiewit's yard on June 19, 2008, for final outfitting. Kewit also built the Perdido topsides at the Ingleside fabrication yard. The spar spent a month and a half at the Ingleside yard in preparation for offshore installation. The spar sailed from the yard on August 8 for the final 150-mile wet tow to its final location in the Perdido field.

### THE MOORING SYSTEM

All of Shell's previous deepwater mooring systems have used steel mooring lines; Perdido is the first to use mooring lines that are primarily polyester. "We've used polyester rope before on drilling and storage structures, but this is Shell's first application for a permanent deepwater drilling and production system," Lohr says. "The 9-inch polyester lines are much lighter than steel, so our decision to use them greatly reduced the payload requirements of the floating structure."

Perdido's mooring system consists of nine anchor lines that average more than two miles in length. The nine taut lines are oriented in a 3x3 pattern, and are anchored to the seabed by 18-foot diameter suction piles that range from 87 to 103 feet in length.

Hereema's SSCV *Balder* entered the Perdido field on June 20, 2008, to install the first cluster of suction piles. Each pile was individually upended, lifted overboard and lowered to the seafloor, where it was oriented correctly before being allowed to penetrate the seabed under its own weight a few feet into the mud. A remotely-operated underwater vehicle (ROV) was used to close the water relief valves at the top of the pile, then to apply suction until the pile reached its target penetration. The water depth of the mooring piles ranged from about 7,600 to 8,600 feet. The installation of pile P6 at 8,631 feet set a new world record for the deepest permanent mooring pile.

Since polyester ropeis more difficult to handle in a winch, the ends of each mooring line are fitted with lengths of chain. On the seabed, ground chains and mooring shackles connect the polyester mooring lines to the suction piles. At the surface, dedicated chain jacks on the platform control tension on the lines. Perdido employs an "active" mooring system, which means that the mooring lines can be pulled in or let out to reposition the spar over drilling locations on the seabed, reaching any point within an area roughly 350 feet in diameter.

### INSTALLING THE SPAR

From Ingleside to the field took two days, and from the moment the spar arrived on August 10, 2008, the activity was nonstop.

All eyes were on the weather until August 18, when the spar became storm-safe with three mooring lines attached The remaining six mooring lines were installed by August 29, just in time for Hurricane Gustav, a storm that briefly

Bert Ulbricht,
Construction lead

Once the spar reached the Perdido site, it was inspected for damage, then brought to the stern of the Balder to connect the water ballast hoses.

Tugs pulled plugs on the soft tank at the bottom of the spar, allowing it to slowly fill with seawater until the incline of the spar reached approximately 15 degrees."

With the water ballast hoses from the Balder connected to the spar, a sequence of tanks were filled to continue the uprighting of the spar. Some 3.5 days after operations began, the spar was upright in the water ready for the mooring lines to be connected.

interrupted operations at the spar, but did not produce any damage. "We spent a considerable amount of time evaluating the risks of installing the spar during hurricane season," says Bert Ulbricht, Perdido Construction lead and Offshore Coordination Team (OCT) lead. "We had statistical weather data, weather windows and flow charts for every step of the offshore operation, starting from when we began pre-setting the first three mooring lines offshore until the time we had all nine of them connected to the spar."

Ulbricht, who joined the project in late 2004 during the concept development phase, was initially responsible for the topsides fabrication, offshore installation, offshore hookup and offshore coordination, but as the project progressed toward the offshore phases, the OCT became his primary focus.

One of the Offshore Coordination Team's key responsibilities was to manage all of the tugs, barges, supply boats, umbilical vessels, the dive vessel, support vessels, anchor handlers, seismic vessels, and the heavy-lift and drilling vessels working in the field. The goal was to coordinate all the offshore activities, from dockside sailaway to first production, and to manage and resolve any vessel conflicts that might impact the offshore schedule.

"The team was a huge success," Ulbricht says. "During the two years of offshore operations, we had between 90 and 100 different vessels that were in the field at one time or another. Throughout the installation of the spar and topsides, there were no marine vessel safety incidents, and we had very little standby time for any of the vessels waiting for another vessel to complete its work."


THIALF
PANAMA R.P.

# THE SINGLE-LIFT TOPSIDES

The Perdido team faced a tough decision. A conventional topsides design required a series of modules that would have to be fabricated onshore, then lifted onto the spar and integrated offshore, but what if the team could constrain the design enough that it could be built and lifted in one piece?

They already knew that Perdido would be a wet tree DVA spar, and were convinced that a single-lift topsides would be safer to build and less expensive than a modular system. The trick was giving the smaller topsides all the capability it needed to produce the field.

"For a development this size we would probably need three modules, so our first big goal was to get the topsides in one piece and keep the weight under about 10,000 tons," says topsides lead, Kurt Shallenberger. "We designed the deck in 2005 to match the lift capability of Heerema's *Thialf* semi-submersible crane vessel (SSCV). Everything we wanted to put on the Perdido spar had to fit within that box."

**Kurt Shallenberger,** Topsides lead

"One of the remarkable things about the Perdido development is that the companies that have worked on this project have turned in record safety performances," says **Robert Paterson,** vice president Upsteam Major Projects, Americas

That was unique. The more familiar way for engineers to work is to let the facility they're designing grow to the size it needs to be. Early weight studies suggested that Perdido's topsides needed to be several modules. Technical benchmarking studies showed that BP's design for Horn Mountain had the best function-to-weight performance of any spar built so far, so with the assistance of BP, Chevron and Alliance Engineering, the Perdido design team evaluated Horn Mountain's design and operating performance.

"That led us to the lightweight Perdido concept," Shallenberger says. "We selected Alliance as the engineering contractor because of its previous experience with Horn Mountain."

## BUILT FOR SAFETY

Health, Safety and Environmental (HSE) needs drove the design of Perdido's topsides. One of noticeable features is the 2.5-bar blast wall that separates the crew quarters from the drilling and processing equipment, but Perdido also has the most aggressive fire suppression and gas monitoring systems of any offshore platform. It is a reflection of how the industry in general is maturing in terms of fire and explosion protection. Planning runs the gamut from how to prevent a release and ignition, to how to mitigate the impact if you do have a fire or explosion, and how best to evacuate the platform.

"Industry has learned a lot, particularly since the 1988 Piper Alpha fire in the North Sea," Shallenberger says. "If there is a gas release, for example, we now have sophisticated models to help us understand where the gas will go. Perdido has more gas detection than any other platform, probably by a factor of five. If we were to detect gas, we can quickly depressure the whole facility and divert the gas to our flare system."

The Perdido design team did extensive modeling of the onboard firefighting capability. Perdido's twin 5,000 gpm firewater pumps and automatic foam system is the most extensive fire protection layout of any Shell platform in the Gulf of Mexico. One revolutionary feature is that the system is automatic. Rather than having a water deluge system and a supplemental foam system, both manually triggered, Perdido's automatic fire suppression system covers the entire platform, including the heliport.

"Computer modeling also helped us determine, if there were an explosion, what kind of overpressure to expect at various points throughout the facility," Shallenberger says. "Blast walls shield not only the crew quarters, but also the safety equipment, work areas and evacuation routes. There are no production offices in the process areas, and the Incident Command Center is adjacent to the control room for real-time feedback. We spent a lot of time in the screening process to make sure that in this compact space, our people are well protected."

## INTEGRATING THE SUBSEA SYSTEMS

Perdido's subsea system, which includes separation and boosting, direct vertical access wells and tiebacks to satellite wells, is a first of its kind.

**Randall Hance,** structural verification engineer, was on the spar site team in Finland.

"Integrating those systems was one of the most complex things we've done on this project," Shallenberger says. "From a topsides perspective, we are looking at recovering oil and gas from a collection of low-energy reservoirs."

The low energy reservoirs demand low boarding pressures to be able to flow at reasonable rates. Gas flows to the surface against 460 psi, while oil is pumped from the seafloor against 160 psi at the surface. Elsewhere in the Gulf of Mexico, deepwater wells flow on their own. On another platform, production might come it at 1,600 psi, which is normally enough to move fluids through the export lines to sales. Since Perdido is so far from the nearest sales line and the reservoirs are low pressure to begin with, the export pressure from the spar is 3,200 psi.

"It takes a lot of horsepower to make that happen," Shallenberger says. "It helps that the liquids and gas are separated on the seabed. On the topsides we separate the oil and water. The gas and oil are exported via two export pipelines, and the produced water is cleaned and discharged overboard. We also have a waterflood, but for that we use seawater."

## FABRICATION SITES

Steel and equipment for the Perdido topsides came from around the world. What designers called the box – the structure that was designed to fit the lifting capabilities of the *Thailf* SSCV – was built at the Kiewit yard in Ingleside, Texas, just across the bay from Corpus Christi. Ingleside is the same facility that completed the spar in 2008. The crew quarters were built at Delta Engineering on the Houston Ship Channel.

## WORKING THROUGH STORMS

Katrina, the most expensive hurricane in U.S. history, made landfall in southeast Louisiana on August 29, 2005. Much of the Perdido team, then in the early stages of design and engineering, was displaced for six months. It was the first big storm to disrupt the project, but not the last.

"When Katrina wrecked the city and Shell's offices in New Orleans, we moved the Perdido team to Houston," Shallenberger says. "We began the front-end engineering and design (FEED) process while we were displaced. That was a big issue for our folks, traveling back and forth, fixing our homes on the weekends and coming back to Houston during the week."

Three years later, when Hurricane Ike made a midnight surge into Galveston Bay and up the Houston Ship Channel, it passed right over the Delta Engineering (now Delcor USA) fabrication yard and Perdido's almost-finished crew quarters. By early morning, much of Galveston was under water, 90 percent of Houston was without power and 100 miles of Texas beaches were gone.

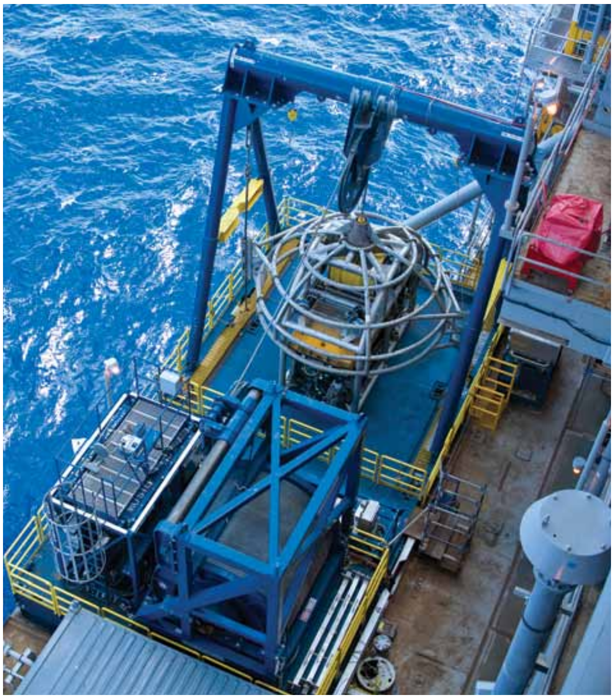
"After our experience with Katrina, we were prepared to deal with Ike," Shallenberger says. "We knew what problems the Delta yard was going to have and we responded right away. Workers were displaced. Most had damage to their homes and families to care for. Since the Delta yard itself was heavily damaged, workers were also concerned about their jobs. We stepped in very quickly to help Delta keep their contract labor employed."

Shell responded with food, water and fuel. Shell's emergency response team even brought in temporary housing and laundry facilities. That support continued for several weeks, until Delta and the rest of Houston got back on its feet. Fortunately, topsides construction at the Kiewit yard was far enough down the Texas coast that it was not affected by Hurricane Ike, and even the crew quarters survived the storm in relatively good shape.

"Perdido's living quarters, which were in the yard at the time of the storm, were not heavily damaged," Shallenberger recalls. "Two days before Ike made landfall, we calculated that if the storm surge came up too high, our quarters building would float off of its supports. We decided to pull the doors off the bottom floor so that if the water did rise,


The design of the topsides depended on the capacity of the heavy lift vessel that would be used to place it on the spar in a single lift. Heerema's *Thailf*, named after a servant of Thor in Norse mythology, is the largest semi-submersible crane vessel in the world. Depending on the configuration of the load and angle of the lift, *Thialf*'s dual cranes can handle up to 14,200 metric tons.

Keith Smith,
Transportation and Installation lead



The topsides design team used extensive 3D modeling and the input from experienced operations staff to plan the location of equipment aboard the spar.

it would get in the lower floor and keep our building from floating. There would be wind and water damage, but we wouldn't lose the whole thing."

**AIR LOGISTICS**

Perdido's distance from its air and marine base in Galveston, more than 200 miles to the north, means that most service boats are 18 hours away, and even a helicopter transport takes at least 90 minutes. Shell, and many other operators in the Gulf of Mexico are using relatively large helicopters so they can evacuate and service their platforms efficiently.

These bigger helicopters, like the twin-engine Sikorsky S-92, can carry up to 19 passengers, but they need plenty of room and a sturdy landing space. Perdido's heliport is large enough for two S-92s. It is built of aluminum, and equipped with advanced safety features to prevent fuel fires on the helipad.

In case a helicopter goes down nearby, most platforms have small, 6-person Zodiac style boats that can reach survivors quickly. With larger helicopters serving the platform, however, the topsides designers needed something bigger. Perdido now includes a 24-person, enclosed, fast-rescue craft.

**HUMAN FACTORS AND MATERIALS HANDLING**

As part of Perdido's safe design, planners used 3D design tools to make things easier for people to operate, service, repair and move around on the platform. To advise Shell's own safety specialists, the design team called in operators with extensive offshore experience and outside experts in Human Factors engineering.

"Every week for two to four hours, we would take a portion of the facility and walk through it in 3D," Shallenberger recalls. "We wanted to understand where things should be: what elevation to put a valve, for example, or where to put a pump and how a person might work on it safely. We made frequent adjustments so that an operator servicing a piece of equipment would not be leaning over at an awkward angle or trying to lift something that was too heavy. We made sure the equipment was as accessible as possible and easy to maintain."

His team studied Materials Handling in the same way. "We looked at all the equipment and determined how often someone might have to work on it. Some things you might not touch for a year, but other items, such as filters, might be replaced twice a month. We wanted those items within easy reach and the replacement parts easy to move. They can't be too high or too low."

If something an operator handles regularly weighs more than 50 pounds, for example, the topsides designers

At the peak of activity, as many as 270 people per shift worked to complete the final hookup and commissioning of the Perdido spar.
Photo Courtesy of Hornbeck Offshore Services.

included room for a cart, dolly or small portable hoist. They also made sure that the cart or lifting system would have room to move around the platform to reach storage areas or outboard cranes.

Other aspects of Material Handling include structural engineering. If a 35,000-pound generator has to come out of it's place in the middle of the platform, will the pathway out be strong enough to support it? Can it be moved to the edge of the deck at a point where cranes can reach it? Will overhead pipes and trays be in the way?

Production people were core members of the Human Factors and Material Handling reviews. Sometimes they would bring along the mechanic or production operator who performed a certain operation so they could explain to the designers and engineers just how the operation was done.

Scott Chitwood,
Topsides Structural lead

"I think we got most of it right," Shallenberger says. "But it would have been hard without 3D modeling; it's a critical design tool."

## TRANSPORTATION AND INSTALLATION

Since the spar had to be towed to site in a horizontal configuration, the deck and quarters had to be integrated offshore. The topsides sailed from Kiewit's Ingleside yard on March 8, 2009. The topsides lift was completed on March 13, and the living quarters were added three days later. At 9,773 short tons, the single-piece lift of the Perdido topsides was the heaviest ever in the U.S. Gulf of Mexico.

## A MODEL FOR ULTRA DEEPWATER

The design of any deepwater project depends on the nature of the reservoirs, water depth, number of wells and a host of other factors. While no single platform can serve every need, the Perdido concept certainly adds new tools to the box.

"This is a very repeatable design," says Dale Snyder, Perdido project manager. "We have put a high degree of functionality into a smaller package than the industry has seen before. We and our JV partners are looking for ways to replicate that in future developments. I wouldn't be surprised if the Perdido concept showed up in other places."

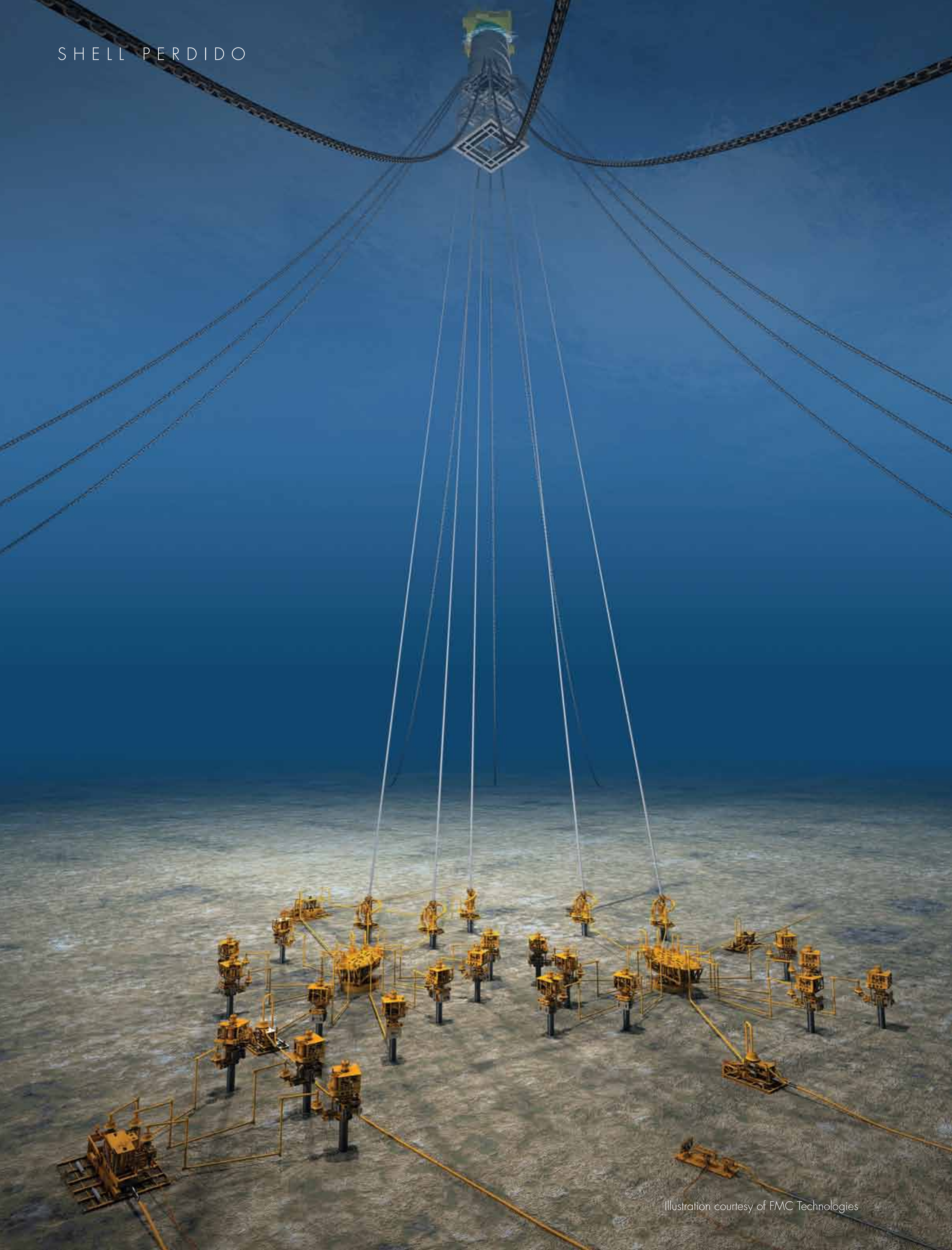


Illustration courtesy of FMC Technologies

# DEVELOPING THE FIELD

Great White, Silvertip and Tobago – the Perdido development's three fields – contain many producing zones, large volumes of hydrocarbons in-place, and a considerable amount of uncertainty.

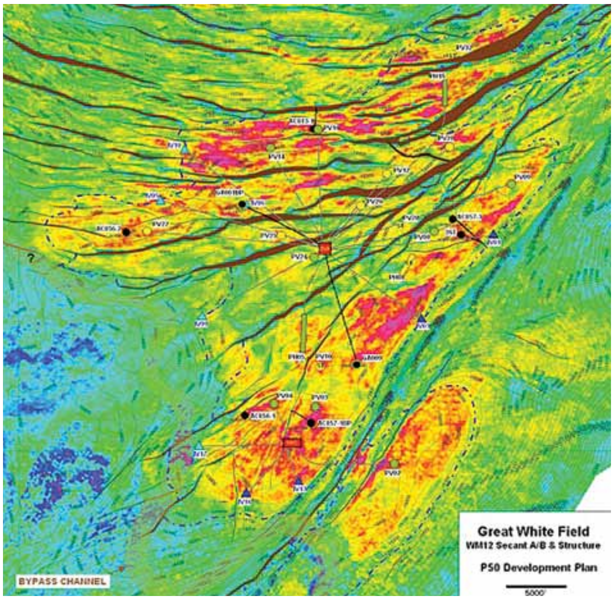
Much of the oil and gas from Perdido will come from the Paleogene geological system, which includes the M. Oligocene Frio Sds., L. Eocene WM12 Sd., and the L. Paleocene WM50 Sds. Together, these three reservoir zones are known as the "Lower Tertiary," reservoir intervals in the Gulf of Mexico that no other operating company in the gulf has tapped before. Some industry analysts are calling the Eocene the most significant oil trend since the discovery of Prudhoe Bay.

"This is a frontier development, which is exciting, but risky," says Vern Eikrem, Perdido's subsurface team leader. "We wanted as much flexibility as possible. We needed a development plan that would allow us to learn over time. That information is important not only for us, but for many other operators in the Gulf of Mexico. What we learn here will determine how we and our competitors go after similar prospects in the future."

A major part of the current plan is to drill as many of the wells as possible from the host platform, rather than from mobile deepwater vessels that complete the wells, then leave the drilling location. That offers two main advantages. First, drilling from your own platform is less expensive than hiring a deepwater rig. Second, having access to the wells from the host platform allows petroleum engineers to learn more about the producing zones and to make adjustments as needed. The downside of drilling most of the wells from a central location is that the wells are often highly deviated, which increases their cost.

Perdido's first satellite wells, of course, were drilled from mobile offshore drilling units (MODUs), which allowed development of the field to start while the spar was being built. In December 2008, the Noble *Clyde Boudreaux* set a world record by completing a production well in 9,356 feet (2,852 meters) of water. The *Boudreaux* also pre-drilled 22 wells to about 2,500 feet below the mud line at the spar location. Two of these wells have been deepened to

**Vern Eikrem,** Perdido Subsurface Team lead




This Great White amplitude and structure map shows the firm development wells in green and the contingent wells in yellow. Wells highlighted with blue circles are the six pre-drilled wells.

the WM12 Sd. The remaining 20 wells will be deepened later to their reservoir targets and then completed. The MODU was released from the field in November 2009 after completing some 2.2 million man hours without a lost-time incident. Development drilling is continuing now from the spar and from Noble's newest ultra-deepwater rig, the *Danny Adkins*.

## A CHALLENGING ENVIRONMENT

Great White, the largest of Perdido's three fields, is one of a series of very large, heavily-faulted anticlines known as the Perdido Fold Belt, which is a very different geological environment than most of the Gulf of Mexico. A deep submarine canyon cuts across the field, and one escarpment near the spar is nearly 1,500 feet (457 meters) high. The reservoirs are also far from other areas of oil and gas production in the gulf.

"That is challenging for many reasons," Eikrem says. "The rugged sea floor makes it harder to install subsea equipment and pipelines, and the extreme water depth makes drilling more difficult. We also have a wide range of permeability in our reservoirs, the reservoir pressure is low, and there are significant differences in the quality of the oil."

On the heavy side, the API gravity in the M. Frio at Silvertip Field is as low as 16 degrees. The lightest oil runs about 38 degrees in the Great White Field's WM50A Sd.

"But even with Perdido's challenges," Eikrem says, "there is real growth potential out here because of the size of our asset. The volume in place is phenomenal. If we can access it economically, this project will go on for many years."

## EARLY DRILLING PROGRAM

Great White was discovered in 2002, and all of Perdido's exploration and appraisal wells were completed by the end of 2004.

"From that point on, we had all of the pre-drill appraisal information we were going to get," says Ed Shumilak, Well Team lead for the spar. "One big question was, where to put the spar. We didn't want it moored in a place where we had to deal with a lot of shallow hazards and subsurface anomalies, so we picked a likely spot, then brought in a floating rig to drill about 1,000 feet below the mudline to evaluate the shallow hazards."

By the end of 2009 the project had eleven exploration and appraisal wells including two sidetracks. In addition, eight development wells had been drilled and six had been completed. The current plan calls for as many as 35 wells, with about two-thirds of them drilled from the spar. The most distant satellite well so far is on the seabed about eight miles from the host. Development drilling is scheduled to continue beyond 2016.

**Ed Shumilak,**
Well Team lead

## RIGGING UP THE SPAR

"When I first started on this project in January 2003, it was wide open," Shumilak says. "We were still trying to figure out what the reservoirs were like, and how in the world we were going to develop something in 8,000 feet of water."

Shumilak's group moved from supporting the Subsurface team to designing the wells, then turned its attention to the spar's drilling rig. Weight was always an issue. Putting wellheads and much of the separation equipment on the seabed made the spar itself smaller and lighter, but the drilling rig was going to add a lot of weight that had to be supported by the buoyancy of the spar.

"Once we decided we were going to put a spar out there, our team began working on specifications for the rig and our interface with the spar," Shumilak says. "We needed a rig powerful enough to drill long, complicated wells, and a spar that could support it. There was a lot of give-and-take, trying to marry the rig to the spar. We worked extensively with the spar and mooring team and with the topsides team."

Building a new rig for the spar would be expensive, and as it turned out, unnecessary. Until 2007, the Helmerich & Payne (H&P) 205 had been on Shell's Ram Powell deepwater platform in the Gulf of Mexico. The rig had a good working history and safety performance, and it was no longer needed on Ram Powell.

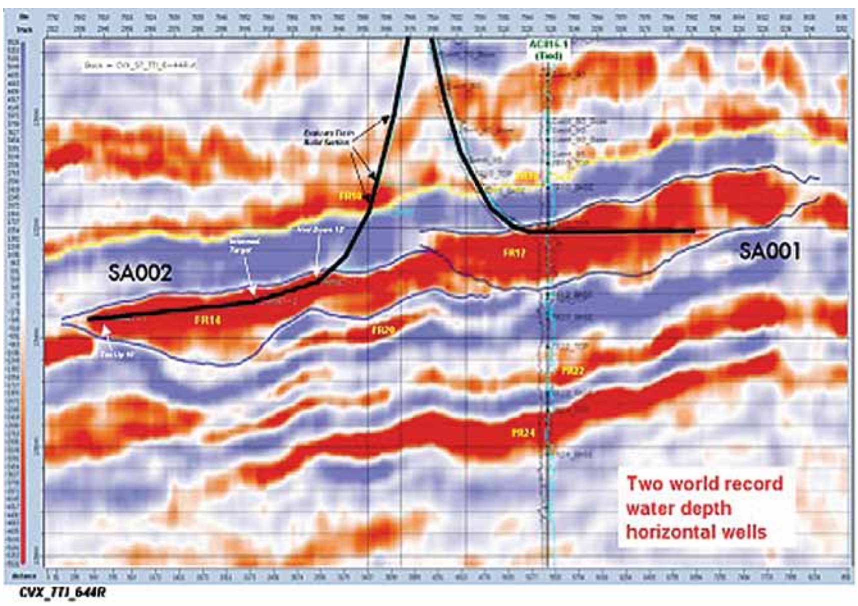
**Erik Sorgard,** Well Delivery Team lead, Perdido Floater Operations

"We demobilized the H&P 205 rig from Ram Powell and took it to the Kiewit Offshore Services yard in Corpus Christi in February of 2007," Shumilak says. "There we made some upgrades, because the rig had been working on a TLP. The motions and stresses are different on a spar, so we needed to modify the rig."

A tension-leg platform, for example, has very little pitch and roll, but it will drift on its mooring lines in a slow figure-eight. Spars don't drift as much, but they will pitch more than a TLP. To compensate, the H&P 205 rig's skid beams and skid base were modified. There were also structural upgrades to the rig floor and derrick.

"The H&P 205 was in the Kiewit yard at the same time they were building our topsides," Shumilak says. "That was convenient, because we could easily go from one to the other. There was a lot of interface management."

The work on the rig was completed in December 2008, but it was not taken offshore until July 2009. The H&P 205 installation was completed the following month and the rig was immediately put to work installing Perdido's first two subsea separator caissons. Most of the experienced crew that had oper-




Two horizontal wells in the Silvertip field set new world water-depth records.


By the end of 2009, Shell employees and contractors had worked more than 10 million hours without a lost-time injury.

One popular and effective safety program with rig construction workers stressed the hazards of dropped objects.

ated the H&P 205 on Ram Powell stayed with the rig and are now on the Perdido spar.

"A number of H&P's rotating crews also work exclusively for Shell, and that enhances our safety program," Shumilak adds. "Even though they move from one facility to another, they know our safety culture. They know the way we work and operate, and they know our foremen and superintendents."

As the rig neared completion in the Kiewit yard, for example, new crew members were brought in to work with the experienced hands. As one of the foremen said, "We're building the safety culture here that we're going to take offshore with us."

One popular safety program is called, *I stopped a drop!* On a drilling rig that is 15 stories tall, dropped objects are a serious hazard. A forgotten tool in the derrick or any small item that vibrates loose can be deadly. As one rig hand explained, "A one-pound bolt falling from 100 feet up makes quite a dent."

Workers who point out such hazards are rewarded, and they have the satisfaction of knowing that they may have kept someone else from getting hurt.

### SAFETY OFFSHORE

Working offshore is inherently dangerous. The work is non-stop. People are moving equipment that weighs tons, yet the offshore safety record for the Perdido development has been outstanding.

"I give a lot of credit to the onsite leadership," Shumilak says. "Day in and day out, the Shell foremen and all the site leads stressed safety. They focused on it in their pre-tour meetings in the morning and in all of their pre-job planning. They talked about safety again at the end of their shift. Safety has been a continual theme offshore, and it really pays off."

The way contractors managed their experienced people is a good example. Anyone who was new to a particular job – regardless of his or her time in the field – was called a "short service" employee. The number of short service employees was kept to a minimum, but when anyone did fall into that category, mentors were always nearby.

**Yvonne Gonzalez,** reservoir engineer, was responsable for surveillance planning.

Because of the extreme water depth, remotely-operated vehicles (ROVs) like this one were used to complete much of the subsea work.

### AN INTEGRATED TEAM

From the beginning of the project through the end of 2009, Perdido's contractors and Shell employees logged more than 10 million man hours without a lost-time injury. That is just one measure of Perdido's success. Shumilak credits a strong integrated team and good management.

"One thing I'm most proud of is the integrated team we had throughout this project, and the freedom that management gave us to explore new ideas, " he says. "We began with a whole range of possibilities and solutions, so we gathered an experienced team of civil engineers, rig folks, subsea engineers and production specialists. The interface and communication was outstanding. Without that, we couldn't have pulled this off."

From the beginning, the team had few constraints. If a project as bold as Perdido was going to be successful, creativity and flexibility were the keys.

"The solution we have right now didn't even come up until three months before we went to decision gate three, which is System Selection," Shumilak says. "We had decided to build a spar with DVA dry trees, but artificial lift and flow assurance were still problem areas. That's when G.T. Ju, our Subsea lead, suggested that we combine the two into a wet-tree DVA system instead."

The design team thought it over. Management gave them two months to evaluate the idea and make a proposal.

"We rounded up all the project leads, explained the idea and started working," Shumilak recalls. "We came back, pitched our case, and management bought in. The ability to do that was fantastic. Without it, I'm sure that our final solution would not have been as good."

# THE EXPORT SYSTEM

The team charged with designing Perdido's oil export system reviewed all their options. There were few. The Perdido spar is moored more than 60 miles south of it's nearest deepwater neighbor. It is 140 miles from the closest shallow-water platform, and the distance in between covers some of the most challenging terrain in the Gulf of Mexico.

The gas export pipeline was routed to the Seahawk Pipeline (107 miles from Perdido), which was installed with subsea facilities for a future connection. The closest oil pipeline, however, had no such connection. Perdido is 77 miles from the Hoover Offshore Oil Pipeline System, commonly called HOOPS. Transportation through HOOPS would require the first installation of a diverless, subsea connection.

"The alternative to a HOOPS subsea connection was to build a pipeline twice as long to the nearest platform on which risers could be installed," says Mike Dupré, Pipeline and Flowline lead. "Taking advantage of the shorter route to HOOPS would require development of a new connection concept."

In a clear break with conventional tie-in projects, a new technique was developed that utilized a truss structure as both a foundation and reference system for the installation of the connection hardware. The foundation enabled the Perdido export connection to be fabricated onshore and reassembled on the pipeline. It was the first time that a tie-in used a common foundation and prefabricated jumper spool.

## THE OIL EXPORT CONNECTION

In shallow water, it is not difficult to tap into a pipeline full of oil, it's called a hot tap, but no one had tried it before in 4,500 feet of water. While the actual connection took just 17 days to complete, preparing for the job took two and a half years.

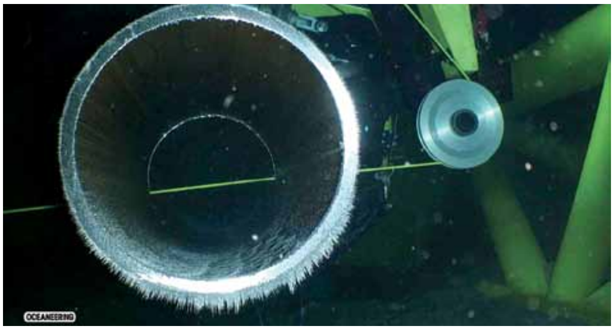
"We learned a lot in that time, and the design evolved," Dupré says. "We applied some new tools, did plenty of 3D modeling, and practiced using ROV simulators to walk through the connection. Because we would be working with a pipeline that has been in service and the majority of the pipeline would still be full of oil, there was no room for error."

In a more typical subsea repair, the pipeline would be shut down, displaced and then cut. Fittings would be placed over each end, then divers or an ROV would measure the

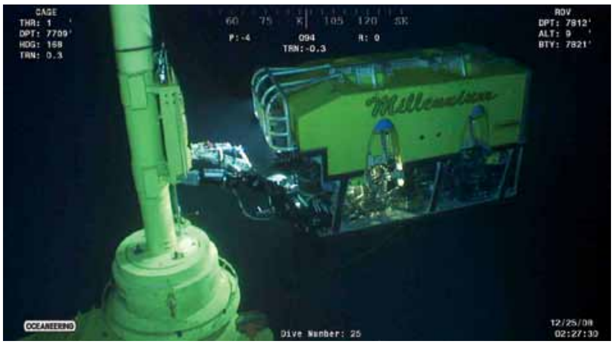
**Mike Dupré,**
Pipeline and Flowline lead

Final assembly of the connection system

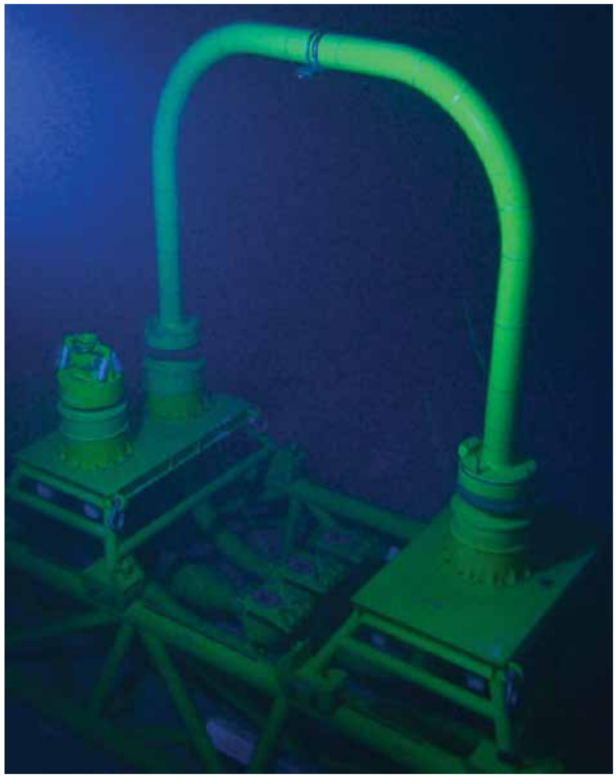
Pipeline End Termination (PLET) units like this one were installed at each end of the flowline.



Cutting the pipe




ROV-assisted installation of the flowline jumper



Completed HOOPS connection

length and orientation of the jumper needed to connect them. The jumper itself would be fabricated onshore and returned to the field for installation. The process would take up to 90 days. Even if divers could work at the depth of the HOOPS connection, the pipeline could not be shut down for that long.

The engineering solution was to create a single structure, a common base that could straddle the pipeline and serve as a positioning reference for tools and the placement of new hardware.

"We started with a simple, conventional design using two sleds and a jumper in between," Dupré says. "There were certain criteria to follow. We couldn't release any oil, of course, we could use only proven components, and we had to minimize the time the pipeline was out of service."

Another criteria was that the connection could be reconfigured in the future. Designers were looking ahead; Hoover-Diana had already been producing for 10 years, so at some point, ExxonMobil might want to disconnect from HOOPS, and new operators in the area might need to tie in.

The key component of the new connection system was a truss-style structure. The structure is 100 feet long, 10 feet tall and 40 feet wide, but made of large diameter members so it could be made buoyant in water. Once it was landed over the pipe, all of the ROV tools and connection components referenced off the base, so every measurement was precise.

"Subsea construction was limited to ROVs and ROV-based tooling," Dupré explains. "Each tool that was deployed was referenced to the foundation. ROV tooling was used to remove the pipe seam, remove the coating, make the cuts and prepare the cut ends. Positioning of the new connection hardware over the cut pipe ends was also referenced to the foundation, allowing precise alignment of components. When it was time to install the final jumper, we didn't have to take measurements and go back to the beach for fabrication. We knew exactly the length and orientation, so we were able to prefabricate the jumper. This allowed the entire operation, which was completed in March 2009, to be completed while impacting production by only 17 days."

**A DELICATE TOUCH**

Since the HOOPS tie-in required placing a large structure over an existing pipeline, designers of the system spent much of their time thinking about how to do it safely. Instead of trying to lower the heavy truss onto the pipe, the truss itself was designed to float. If the truss broke free, the structure was going up, not down.

As the truss neared its target, ROVs secured clamps to pull it down over the pipeline. Once the truss was positioned properly, the hollow pipes in its frame were progressively flooded until the 100,000-pound structure was embedded fully in the seabed. Using this stable base, the pipeline was then raised a short distance to allow 360-degree access for the tools.

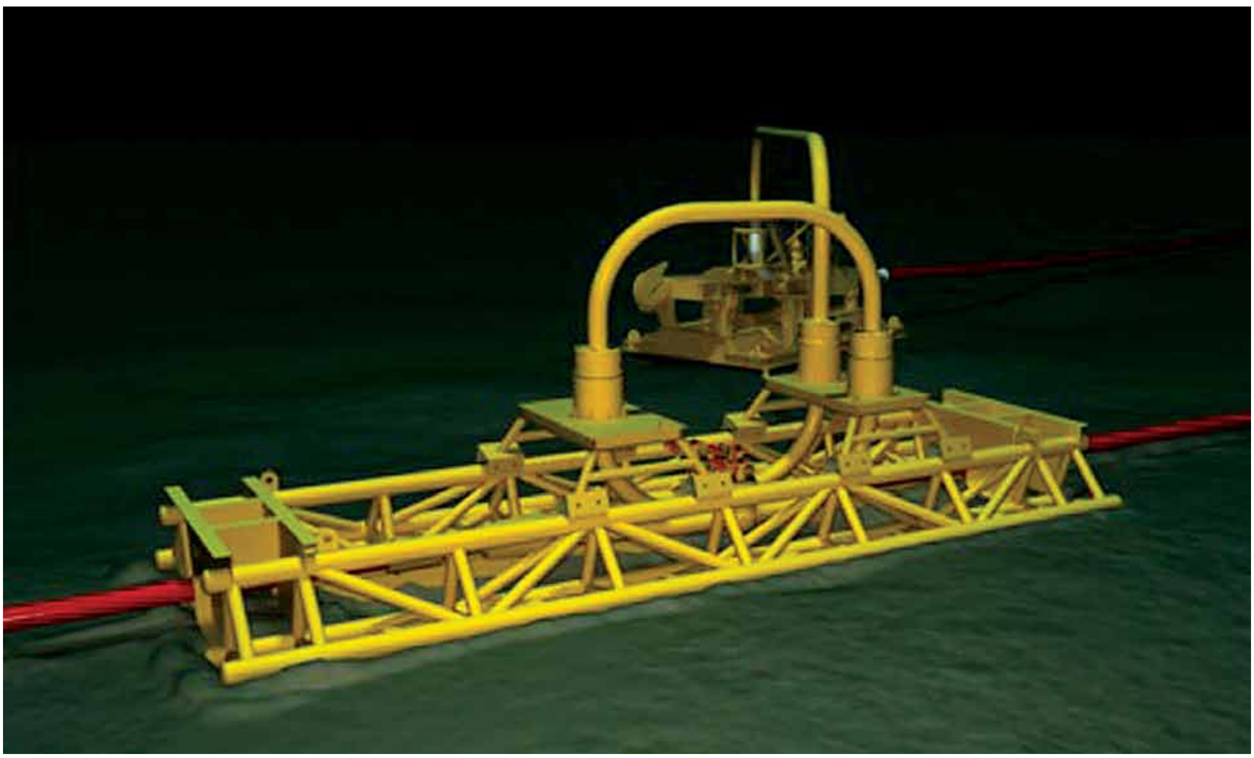
"So the frame went in first," Dupré says. "Then we had to clean and cut the pipe. We needed to take out a total of 28 feet from the middle."

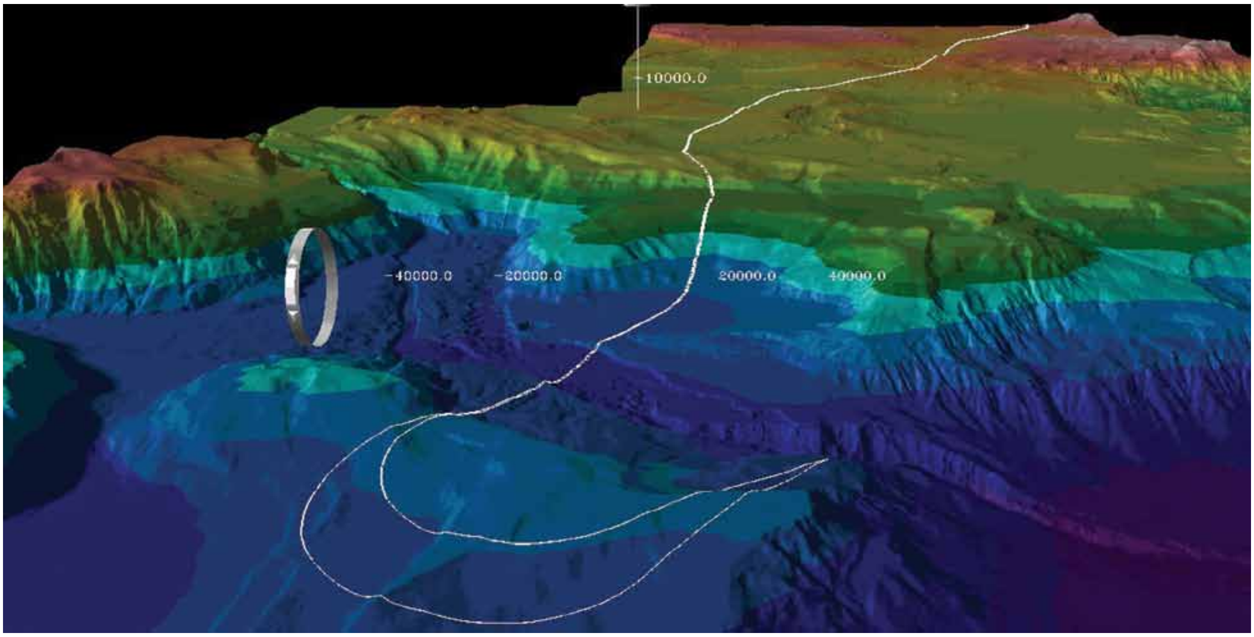
To thoroughly clean the pipe, the team ran a series of four high-tech pigs from the Hoover platform. Radioactive markers inside the pigs allowed the pigs to be tracked and positioned in the line.

Between each pig was a slug of water. Pigs one and two were allowed to pass the point where the pipeline would be cut, while pigs three and four were stopped before they reached the cut point. Between pigs two and three, the pipeline would contain only water, but no one wanted to take a chance on spilling any oil.

"In addition to the positioning of slugs of water and operational procedures applied at the upstream and downstream risers, we had a contingency repair clamp positioned on the pipeline next to the cut point to re-seal the pipe in case there was still some oil in the line," Dupré says. "We also had a pollution dome over the top of the frame, so if we had any oil, we could capture it and pump it into a subsea reservoir for recovery. We had all of these contingencies in place, but when we made the cut, nothing came out. The pipeline was completely clean."

The HOOPS connection system has four main components: a single hub assembly affixed to the upstream pipeline, a dual hub assembly affixed to the downstream pipeline, a foundation that serves as the structural support and reference system, and the pipeline jumper to restore the flow path of the existing pipeline.






## THE FLOWLINE SYSTEM

As pipeline engineers like to complain, drillers always manage to find oil in the worst possible place. Perdido is a prime example. Besides the extreme water depth, there's a wide and 1,000-foot deep canyon just north of the spar, between the spar and the export systems. To the south and east, the export and the subsea lines to satellite wells also had to avoid steep slopes and chemosynthetic communities of environmentally-sensitive creatures.

Surveys covered more than 1,000 miles of the sea floor to find suitable routes. As a result, all of Perdido's flowlines now run through very narrow corridors. Even the export lines exit the spar to the south, then make a large u-turn before heading north.

**Sally Simmers,** flowline engineer, managed the flowline and riser installation contracts.

"On the flowline side, we're having to contend with extremely deep water," Dupré says. "Some of our flowlines are more than 9,700 feet deep. That means some of them are shorter than the water depth, which makes it much harder to install the lines from a vessel on the surface. At some point, the entire flowline is hanging below the vessel."

The flowline system is comprised of production flowlines, water injection flowlines, and utility lines to circulate oil for flow assurance. Each had it own unique design criteria. Insulated with GSPU (a wet insulation for subsea pipelines), the production lines extended to the deepest portions of the field, routed around deep slopes and seafloor features. The water injection flowlines utilized both an internal and external fusion-bonded epoxy (FBE) coating. An alternative to a clad pipe or polymer liners, the internal FBE provides corrosion protection to prevent potential plugging of the water injectors. Even the small diameter circulation line provided unique challenges in routing across a difficult seafloor, where piles had to be installed to accommodate the multiple spans. In addition, because of installation vessel availability, this majority of the construction was completed during an active 2008 hurricane season.

"The Perdido Pipeline and Flowline Team kept its focus on safety, overcoming many technical challenges to deliver a robust solution for the Perdido Project," Dupré says.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# OPERATIONS AND SURVEILLANCE

Experienced operators practice running a new field long before first oil. What's unique about Perdido is that some of the systems – such as the wet-tree direct vertical access wells and the subsea separators – are industry firsts.

"On Perdido, the design team pulled Operations into every aspect of designing the topsides," says Chris Smith, Perdido Operations manager. "At the end of the day, the project had our handprints all over it. Operation's Arthur McAlpin was so instrumental in the design of the helideck, for example, that it's nicknamed *McAlpin International*."

"Four years before first oil, we began drawing staff from eighteen upstream and downstream locations to build the Perdido Operations team," Smith says. "As we built the organization, we focused on team building to insure the success of our operation and the people who run it."

**THE HOME TEAM**

"The core of Perdido's operating staff joined the project during the front-end engineering and design process," says Arnold Marsden, who recently took over for Bert Garcia in April 2009 as Perdido's Safety lead. "That team grew over time to the full complement of people it takes to operate the platform. Twelve months before startup, we were fully staffed."

Much of their time was spent running simulations, first on paper, then using advanced simulators and system modeling tools. Their job was to detail all the steps needed to start the facility and keep it running safely.

"They were looking for ways to do things safer, better, and faster," Marsden says. "In doing that, the operations people become very familiar with the system."

Another part of the work was to document all of the major health, safety and environmental risks, and to demonstrate how they are being managed. That helped the Operations team identify all of the procedures, maintenance jobs, inspections, emergency response people and equipment they'd need. The goal was to minimize risks. A helicopter landing officer, for example, is responsible for making sure the helipad is clear of debris, that people aren't on the pad, and that a firefighter is standing by when an aircraft is coming in.

Chris Smith, Perdido Operations manager

"That's what we call an HSE Critical Activity," Marsden says. "We put someone in charge because it is a major risk. In this case, we specify that certain duties are critical to preventing a major helicopter incident. We have identified hundreds of HSE Critical Activities for different people. We make sure they know that what they're doing not only protects them, but everyone else on the platform."

Learning is an ongoing activity, but much of the training for Perdido's Operations staff came from being involved early on with the design and construction of the facilities. By the time Development was ready to hand over the keys, the Operations people were all experienced hands.

"The HSE case at the end is kind of anticlimactic, because, quite frankly, all of the operations folks are all very familiar with the platform, the risks, and their roles in preventing accidents," Marsden says. "Unless there has been a last-minute adjustment, even the newest operators have been on board for some time. Their training was excellent."

**Arnold Marsden,**
Perdido Safety lead

**TRANSIENT ENGINEERING SIMULATOR**

One of the first operating and surveillance tools the Perdido team developed was the Transient Engineering Simulator (TES).

"To understand and model the behavior of our wells, flowlines, and especially the artificial lift system, we needed to know Perdido's fluid properties and flow conditions throughout the system," says Gill Purdy, Production Technician.

Illustration courtesy of FMC Technologies

A typical steady-state multiphase flow analysis yielded overall pressures and temperatures, which allowed the Operations team to plan for chemical injection, pipeline sizes and strategies for insulating the pipe. To predict the complex multiphase physics of Perdido's closed-loop artificial lift system, however, they needed a Transient Engineering Simulator.

"Our simulator has a very intuitive interface," Purdy says. "It is similar to operating the field with a Distributed Control System (DCS) that is equipped with a human-machine interface (HMI). Even parameters that are not instrumented in the field, such as pressure, temperature and liquid holdup throughout the flowlines and wellbores, are available in the simulator."

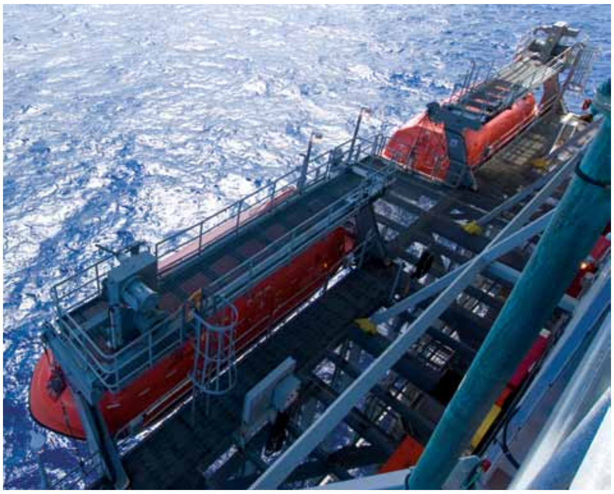
On a PC laptop, the program can simulate three flowlines, five caissons with electric submersible pumps (ESPs), up to five multiphase concentric annular risers and more than 20 wells, all at speeds up to 20 times faster than real time.

"With this tool, we can study the health and behavior of our ESPs, manage the complex subsea boosting system and guide ourselves through transient situations, such as unplanned shutdowns," Purdy says. "And since the simulator can run in a stand-alone mode, onshore surveillance support people can use it to optimize procedures as the field ages, or as a risk-management tool to study rare events such as aborted startups, interrupted blowdowns and cold-oil sweeps. Since the interface runs much faster than real time, it's easy to investigate many circumstances and responses."

## OPERATIONS TRAINING SIMULATOR

The TES model itself became the calculation engine for an Operator Training Simulator (OTS), which runs the actual control code on the distributed-control system's human-machine interface offshore. That allowed operators to train using realistic scenarios. The accurate physics of the simulator helped them test and refine procedures in relation to controls, instrument readings and human response.

"Our operator training program was a mix of classroom theory, guided lectures using the OTS, and hands-on exercises with one of our quad-monitor workstations," Purdy says. "That realistic interaction generated both a high-quality learning experience for the operators and an extended shakedown of the operating system."



Safety was the guiding principle in Perdido's design and the training of its operating staff

## ESP SURVEILLANCE TOOLS

The Subsea Boosting System is one of the major new technologies deployed at Perdido. It consists of a 350-foot-long cyclonic vertical caisson separator that separates oil and gas on the seabed, directly beneath the spar. A powerful electrical submersible pump (ESP) at the bottom of the separator pumps liquids to the surface, while the gas flows to the surface on its own.

The ideal operating condition for the ESP is to maintain the liquid level at a point about half way up the separator

**Jason Gage,** senior civil engineer, was responsible for the structural design verification of the spar.

vessel. The ESP's performance depends on the properties of the fluid it is trying to move. More viscous fluids decrease the pump's boost at a given flow rate, while entrained gas reduces the effectiveness of the impellers. Performance and reliability in general require a good understanding of the subsea boosting system and the caisson riser, and there is plenty of incentive to keep them running for a long time. Changing out an electric submersible pump can cost millions of dollars and weeks of deferred production.

## INTEGRATED PRODUCTION SYSTEM MODELING

Building a fit-for-purpose Integrated Production System Model (IPSM) for Perdido posed several unique challenges. The production system uses unconventional separation and lift technology that is difficult to model, and even trickier to integrate with other models.

"Perdido's phased development plan needed a model that worked for both daily surveillance and for long-term development planning." Purdy says. "Through a collaborative effort that drew on global expertise across many disciplines, the ISP and the model that Shell developed for Perdido began to add value long before first oil."

The challenge in developing the IPSM for Perdido was the complex nature of its unique production system. Perdido also produces from fields that vary significantly in fluid properties. Recirculation lines that can route production from the surface back to the separator caissons adds yet another layer of complexity.

"The process of simplifying this complex technology into an integrated model required many approaches," Purdy says. "By sharing knowledge with other Shell surveillance teams, we developed an improved solution to model the subsurface boosting system. The final product addresses both pump curve limits and the impact of changing fluid properties on a pump's performance."

To make the IPSM more user friendly for those with less modeling experience, a model manager was built in Excel software. It allows users to run scenarios in three modes: First, with only the reservoirs and wells, second, up to the caissons and the ESP, and third, with simplified surface facilities on. Results of multiple scenarios are automatically recorded in the model manager so the user can easily compare potential gains or losses.

## INFORMATION TECHNOLOGIES AND PROCESSES

Satellites connect Perdido to onshore engineering support centers in Houston and New Orleans. These links provide secure access to the process control network in one of two ways. First, through the Process Control Access Domain (PCAD), and second, through direct connection to the Remote Control Room in New Orleans.

In addition to voice communications, the link supports a range of data acquisition and collaboration, enabling support staff and subject matter experts to work remotely.


Perdido's first oil was announced in New York City's Times Square on March 31, 2010.

The Process Control Access Domain allows controlled access to specific computers within the process control network. Through the PCAD, technical support staff in remote locations are granted access to select systems, which eliminates the need for the additional support staff to actually be aboard Perdido.

The remote control room (RCR) in New Orleans is an extension of the Perdido-based central control room. It is staffed by experienced control room operators who have full access to systems on Perdido. This facility allows surveillance engineers, Operations support staff, and technical support located in New Orleans to directly interact with the Operations people offshore. Video links between the RCR and Perdido's control room enable operators in these two locations to interact directly. Remote access also allows surveillance engineers and vendors to see exactly what the offshore operators are seeing on their computers, which achieves a higher level of support.

"Although operating in ultra-deepwater is very challenging, the early use of our Surveillance and Operational tools allowed a smooth startup of this important asset," Purdy says. "These technologies will also let us continue learning the reservoirs and improving our operation for many years to come."

**PERDIDO'S FLOATING HOTEL**

For more than eight months in 2009, most of Perdido's offshore workforce lived aboard the *HOS Achiever*, a 430-foot multi-purpose service vessel (MPSV) operated by Hornbeck Offshore Services.

The dynamically-positioned *Achiever,* which normally carries fewer than 30 people at a time, was reconfigured to accommodate as many as 283 passengers and crew. Over the course of Perdido's hookup and commissioning phase, there were more than 47,300 cumulative personnel transfers between the *Achiever* and the spar.

COMPANY PROFILE

# FISHER® DIGITAL VALVES WITH PREDICTIVE DIAGNOSTICS PROVIDE OPTIMAL PERFORMANCE AND INCREASE PROCESS SYSTEM UPTIME

Emerson Process Management worked in partnership with Shell to develop and manufacture nearly 100 custom and severe service Fisher® digital valves. These valve solutions cover all process control aspects of the challenging, ultra-deepwater Perdido platform located in the Gulf of Mexico.

The Perdido platform's central control system utilizes Fisher digital valves with Emerson-developed Asset Management Software (AMS™) and the AMS ValveLink™ SNAP-ON™ application to monitor the process control equipment for optimal performance. This unique software solution utilizes predictive diagnostics to open a window to the process by giving a view of the valve's actual position and operating characteristics as well as diagnostics of the entire valve assembly and instrument.

Fisher digital valves with predictive diagnostics provide Shell with the power to improve process availability and increase platform reliability.

Utilizing reliable Fisher digital valves with performance diagnostics has provided Perdido personnel the opportunity to make better-informed decisions, leading to increased safety, increased availability, reduced variability, process optimization, increased throughput and enhanced product quality.

EMERSON
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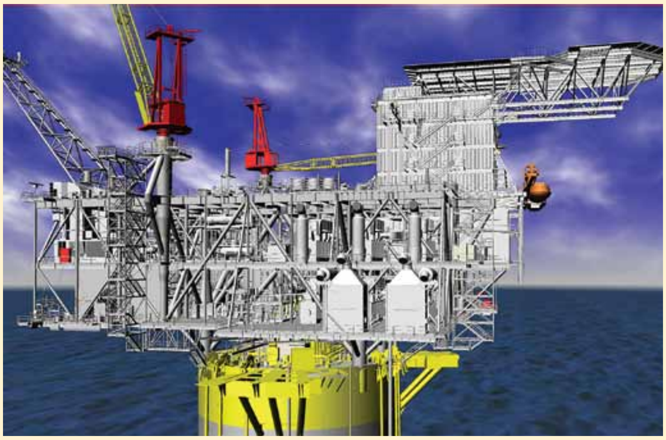
# ALLIANCE ENGINEERING'S LIGHTWEIGHT TOPSIDES DESIGNS RESULT IN EFFICIENT, LOWER COST FACILITIES FOR PERDIDO




Alliance Engineering uses 3D design software to bring projects to life before they are built.

Alliance Engineering, a Wood Group Company, has expertise in successfully developing topsides for major offshore fields for a variety of project types, including deepwater platform topsides, floating production, storage and offloading (FPSO) unit topsides, and fixed structures. In particular, Alliance has a well-established and well-earned reputation for designing and implementing lightweight, single-lift deepwater topsides. Alliance is associated with numerous world records, including the deepest tension-leg platform (TLP), deepest spar, deepest semi-submersible platform, deepest dry tree unit, first dry tree mini-TLP, and first mini TLP.

This reputation is one reason Shell chose Alliance to provide front-end engineering and design and detailed design of the Perdido spar topsides. Alliance also provided conceptual design services, fabrication and installation support, and commissioning support for the unique topsides.

## Reducing weight at every opportunity

The topsides design techniques were a key enabler to permit Shell to advance the Perdido project. Designing a deck for single-lift installation avoids redundant steel weight and results in improved deck space utilization, lower installation cost, more complete pre-commissioning, and faster offshore hook-up and commissioning. A lightweight topsides reduces hull displacement and mooring loads, provides a faster overall project schedule, and improves overall project economics.

In partnership with Shell, Alliance demonstrated ingenuity and flexibility by engineering a fit-for-purpose topsides design by investigating and implementing many solutions to reduce weight. Alliance challenged equipment suppliers to reduce the size and weight of their equipment. Combined with Shell's innovative solutions to reduce the riser load on the spar, this approach resulted in significant weight reduction and a significant savings in time and cost. The facility accommodates production from five subsea direct vertical access separation caissons.

## Sophisticated instrumentation and control

Alliance worked very closely with the main automation contractor to design and implement a world class facility control system for Perdido. Every facet of the facility's processes, including topsides, hull, and subsea, can be managed from Perdido's central control room. The process control portion of Perdido's facility control system is based on Yokogawa's Centum CS 3000 distributed control system (DCS). For safety shutdown and emergency support, Yokogawa's ProSafe RS for safety integrated systems was used. The ProSafe RS is a TUV SIL-3 rated safety system.

The Centum CS 3000 DCS and ProSafe RS safety system communicate seamlessly, allowing safe integration of the controls and shutdown systems for the facility.

## Project success

The topsides were installed onto the Perdido spar in March 2009. At 9,350 short tons of the deck, excluding rigging and materials, this lift is the heaviest ever made in the Gulf of Mexico. At a water depth of 7,817 feet, Perdido is the world's deepest spar.

Alliance Engineering
A Wood Group Company

**Alliance Wood Group Engineering, L.P.**
330 Barker Cypress Rd.
Houston, TX 77094
Tel: 281-828-6000
Website: www.alliance-engineering.com

# FIVE ENHANCED RUN LIFE ESPS AT THE HEART OF PERDIDO SEAFLOOR SEPARATION, BOOSTING STATIONS

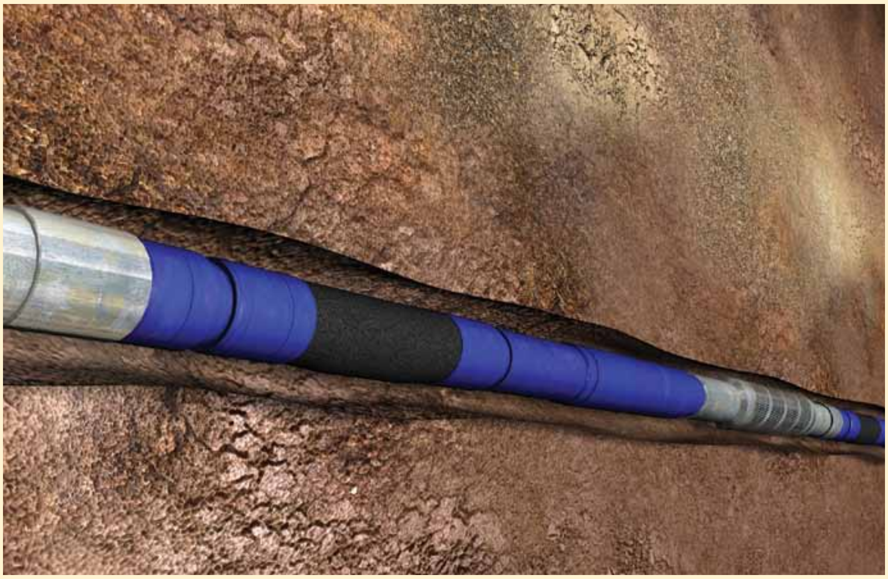
## Installed in 350-ft caissons where cyclonic separation takes place, pumping systems can move up to 125,000 b/d while helping conquer extreme back, spar riser head pressures

Because the Perdido Regional Development involves three widely spaced, ultra-deepwater fields whose reservoirs are made up of older rock with tighter porosity and permeability along with low temperatures and pressures, Shell Exploration and Production (Shell) decided early on to handle all production via equipment placed on the sea floor, including artificially lifting production liquids to the Perdido spar topsides from a water depth of more than 8,000 ft (2439m).

Under this accelerated production plan, Shell would route the gathered oil and natural gas from 35 subsea completions – including 22 wet-tree, Direct Vertical Access (DVA) wells clustered beneath the Perdido spar itself – through two seafloor manifolds and then into five separate vertical processing and boosting stations, each installed on the sea floor in close proximity to the spar and each armed with a powerful electrical submersible pumping (ESP) system.

For this vital system, Shell in December 2006 chose Baker Hughes Centrilift and its innovative array of enhanced ESP run life subsea production solutions. Other Baker Hughes products, including a number of Baker Oil Tools downhole safety and production management and monitoring products, are being installed during completion of the subsea wells, which is still ongoing.

The Centrilift ESPs, however, would be set just below the mud line inside five pre-drilled, 350-ft (92-m) deep, 36-in (91-cm) diameter caissons directly connected to the spar's production risers. There, cylindrical-cyclonic separation and ESP boosting would take place. The caissons, lowered into five so-called shallow "dummy" wells, and the ESPs, each encased in a pressure vessel with an inlet/outlet connection system on top, would be installed by a construction vessel to await first production.



Baker Oil Tools' MPas one-trip isolation packers are the industry's only non-inflatable mechanical packers that conform to irregular wellbore geometries.

Combined, the 10-in. diameter,1,600-hp ESPs are capable of delivering up to 125,000 b/d of oil and associated natural gas from the Perdido fields – Silvertip, Tobago and Great White – to the spar topsides.

The Perdido seafloor production handling setup is the world's deepest application of a full host-scale subsea separating and boosting system, and will remove fluid back pressure on the wells, particularly those completed at Silvertip and Tobago, which will reach the processing/boosting system in lengthy 10-in. (25-cm) seafloor flow lines, some up to 30 miles (48 km) or more in length.

### ESPs the only subsea boosting system qualified for ultra-deepwater

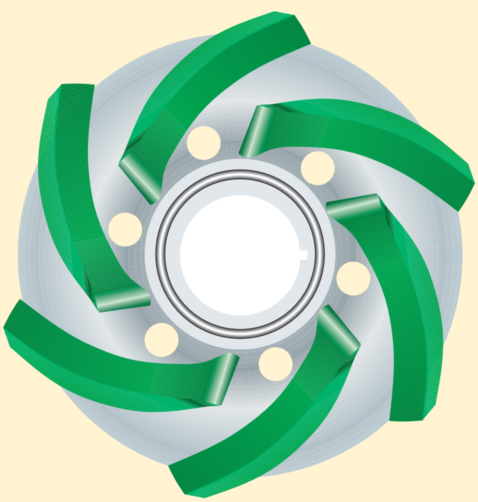
As noted, Perdido Regional Development wells tap older Paleocene reservoirs, which exhibit sub-normal flowing tubing head pressures – about 750 psi – compared to younger Gulf of Mexico pools. However, once arriving directly below the Perdido spar, the fields' multiphase flow will be confronted with a head pressure exerted by 8,000 ft of fluid in the risers, hence the need for artificial lift. ESP systems were chosen for this project because they were the only subsea pumping systems designed to operate at these water depths and corresponding pressures.

In caisson separation, the multiphase fluids are conditioned in the inlet piping and enter the caisson at a downward angle and at a tangent, which causes the fluids to disengage from the gas. Gravity, in turn, causes the separated gas to travel upward inside the production riser tubing annulus. Meanwhile, the tangential velocity inside the caisson keeps the oil/water fluids from re-entraining with the gas, which swirl downwards to the bottom of the caisson, where the ESP then pumps them through dedicated tubing inside the production riser for topsides handling.

Whatever the horsepower/pump rating, Centrilift ESPs are specifically designed to handle high gas volume fractions (GVF). This is particularly important for seabed boosting systems, where gas content can be significant, such as at Perdido. The multiphase pump technology includes the ESPs' patented split-vane impeller design, which is key to keeping gas from accumulating in the pump and locking it. Under certain circumstances, Centrilift ESPs can handle up to 70% GVF without gas locking.

Subsea separation/boosting exhibits a number of enhanced run life benefits. For example, once the gas is removed from the flow stream, the heat retained in the fluid phase, coupled with the high flow capacity of the ESP, helps prevent hydrate formation. For that reason, Shell did not specify physical heating elements for the Perdido caissons or pumps.

However, Shell did award Baker Hughes with the contract for chemical engineering and design services, with a list of deliverables that included flow assurance, monitoring and surveillance, chemical injection, chemical product development and others. Baker Hughes also was awarded with the first fill contract in 2009, along with a one-year contract to supply chemicals and chemical services.



Baker Hughes' multi-phase pump technology includes ESP split-vane impeller design

## SURELIFT gauges, monitoring tools

Each Perdido ESP package is equipped with a number of Baker Hughes Intelligent Production Systems' SURELIFT™ gauging and monitoring instruments designed to optimize output from the ESPs. All SURELIFT instruments are connected inside the ESP pressure vessel by a single mono-conductor cable to power the sensors and transfer the signal cleanly to the surface.

Among the SURELIFT sensors and gauges on each ESP package are:

- The SURELIFT/E Pod, which connects to the bottom of the lower ESP motor and interfaces with resistance temperature device (RTD) sensors for real-time motor winding temperatures along with lower-caisson pressures/temperatures.
- The SURELIFT/E Fixed-Venturi Flow Meter Carrier, which houses a dual gauge for monitoring real-time ESP flow rate and discharge data.
- The SURELIFT/E Dual-Gauge Carrier, which houses a dual gauge whose lower end supplies density and temperature data and whose upper end supplies real-time pressures/temperatures from the middle-caisson level.
- The SURELIFT/E Single-Gauge Carrier, which supplies upper-caisson level pressures/temperature.
- The SURELIFT/E Vibration Sensor, which connects to the ESP intake pump to measure dual X and Y vibrations.

Additionally, Baker Hughes' ESP/Intelligent Production Systems data specialists are working closely with Shell's Perdido commissioning team to assure that all SURELIFT real-time data interface with Shell's SCADA worldwide monitoring system.

Rounding out hardware installations for the ESP installations are the Baker Hughes ESP cable/control line cutting tool, a mechanically operated device designed to cut through the ESP cable, the tubular encased conductor (TEC) wire and chemical injection pack in the event the tubing inside a production riser must be cut and retrieved. The cutter is a critical component of a systems solution approach to intervention.

While Baker Hughes is in the forefront of subsea processing and boosting technology, it also historically has been a key provider of drilling and completions equipment and services, and continues to contribute significantly to preparing Perdido wells for production.

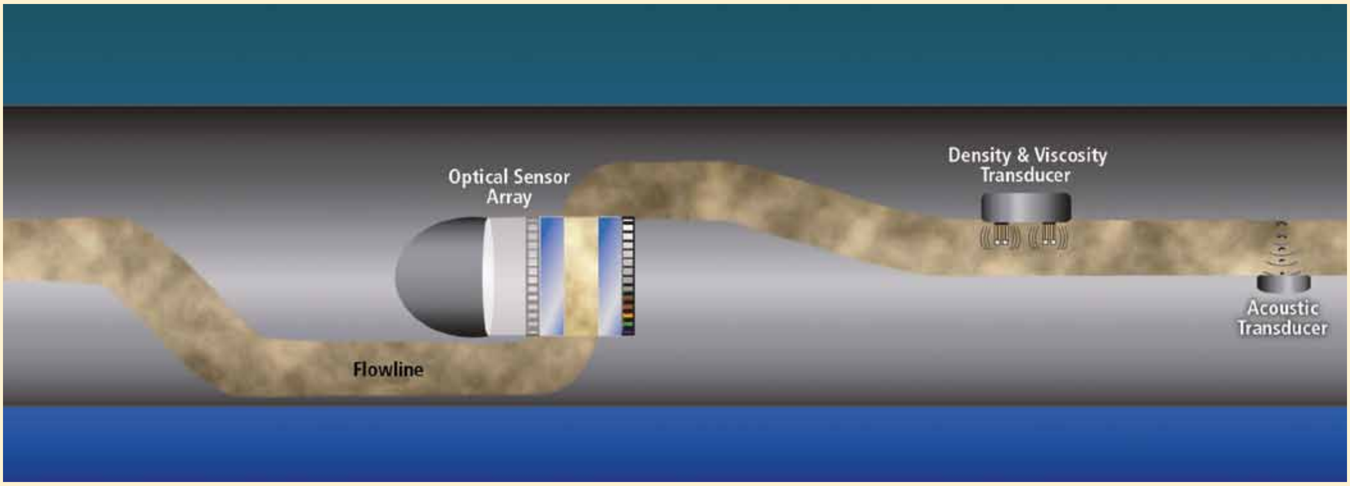
## One trip, multiple sampling

In the realm of formation evaluation, Baker Hughes is providing new downhole tools designed to record formation pressures and collect multiple, high-purity samples of formation fluid types and behaviors and then deliver the data to the surface in real time, all in a single trip of the tool array.

Chief among those being utilized in Perdido wells is the Reservoir Characterization Instrument™ (RCI) string, a wire line-conveyed package that takes large-volume, early development samples of well fluids, along with formation pressures and temperatures, and takes them during only one trip into the hole.

The RCI tool can be configured with a straddle sealing array, which employs a modular design for operational flexibility. This overcomes limitations placed on the standard probe configuration in fractured, vuggy and tight-borehole formations. The twin inflatable sealing elements are set in the borehole mud cake wall to isolate a 1-m (3.3-ft) test section, exposing a larger sampling area that requires less draw down.

Included in the RCI string being used in Perdido wells is Baker Hughes' new In-Situ




The Baker Atlas IFX tool has transducers for measuring fluid density, viscosity and sound speed. The optical sensor array provides light absorbance spectra, UV fluorescence spectra, and a continuous refractometer.

Fluids eXplorer™ tool, which monitors the real-time physical properties of the fluids being pumped from the formation through the RCI tool. This tool also takes samples in volumes that total up to 4.8 quarts (4.5 liters) and holds them in multiple sealed carriers for later hands-on examination. This capability far exceeds that of traditional wire line formation test tools, which are capable of taking only a few, sometimes highly contaminated formation fluid samples.

Other RCI tool applications include vertical interference testing, rock strength determination and cased-hole testing and sampling.

## SCSSVs, real-time completion measurements

For well completions, Baker Hughes is supplying Perdido wells with Neptune™ nitrogen-charged, tubing-retrievable surface controlled subsurface safety valves (SCSSV), which feature innovative non-elastomeric seal technology – an industry first for nitrogen-charged valves.

Additionally, for the 22 subsea completions in the Great White field, Shell chose Baker Oil Tools' MPas™ one-trip mechanical isolation packers, the industry's only non-inflatable mechanical packer that conforms to irregular wellbore geometries.

Run as an integral part of the casing or liner string, the MPas packer uses an elastomeric element with composite structure that is hydraulically set. Shifting a balance sleeve allows wellbore hydrostatic pressure to act against an atmospheric chamber, which applies the setting force. A lock mechanism maintains the setting force for the life of the well, even if hydrostatic pressure is removed.

Also, as part of well completion hardware, Baker Atlas ran cement bond integrity measurements using its segmented bond tool (SBT), which provides 360-deg. evaluation of cement bonding to identify any channels in the cement annulus which could result in a poor hydraulic seal and, conversely, find zones of uniform bonding across only a few feet of casing. The data can help avoid costly squeeze cementing procedures.

The Baker Oil Tools Neptune series nitrogen-charged tubing-retrievable surface-controlled subsurface safety valve is designed for completions requiring low operating pressures due to control system limitations.

For ease of interpretation, SBT measurements are displayed in two log presentations, both of which are available in the logging mode as the data are acquired, processed, and plotted in real time.

Finally, on some Perdido wells, Baker Hughes completion engineering specialists are running Real-Time Compaction Imaging (RTCI) logs, which use fiber-optic sensors to monitor sand screen and casing deformation. The RTCI service was co-developed by Baker Hughes and Shell.

Because undetected completion deformations can lead to costly workovers, lost production, and even the potential of loss of the entire well, Shell took advantage of the RTCI technology, which uses thousands of sensors incorporated within the sand screen instrumented with optical fibers to monitor strain and acquire a 3D, high-resolution deformation image of the screen in real time.

Shell plans to re-run compaction logs throughout the life of the wells.

BAKER HUGHES

**Baker Hughes**
2929 Allen Parkway
Houston, Texas 77019
Tel: 713-439-8135 • Fax: 713-439-8600
Email: Kathy.shirley@bakerhughes.com
Website: www.bakerhughes.com

# FEDERAL PROVIDES THE KEY CONNECTIONS FOR SHELL PERDIDO

Federal Flange Inc. (Federal) has been providing specialty pipe connectors and flanges to the oil and gas industry for over 30 years. Our business has been built upon a platform of unsurpassed quality, custom-engineered solutions and a passion for customer service. This is supported by a state-of-the-art manufacturing facility, a world-class engineering staff and a business model which provides the flexibility to meet our customers' most challenging demands.

## The Shell Perdido Challenge

Federal was asked to provide the majority of the pipe fittings and flanges for the Perdido Host tie-in to the Silver Tip, Great White and Tobago fields. This included requirements in a range of materials suitable for the unforgiving environment in which these components would be placed in service.

The fitting's materials of construction comprised a microalloyed steel of $S_Y$ of 70 ksi, and a martensitic stainless steel alloy in both ANSI and API geometries to meet the client's specifications. A truncated list of the items provided in this undertaking include bulkhead anchors, pressure transmitter tees, flow tees, reducing tees, block elbows, riser hang off collars and swivel flanges. In addition, we sourced a wide range of ANSI/API flanges in sizes from a nominal 6–in. to 16–in. with varying wall thicknesses for the various flow lines and sleds. Design conditions varied from Class 1500 ANSI to 10K API over the sizes and materials aforementioned.

Our responsibilities included detailed design, materials procurement, heat treatment, quality control and manufacture and post fabrication inspection. Over the course of the project there were several required amendments significantly affecting item quantities with an overall order magnitude totaling some 780 ft of forged pipe and 240 assorted components. Even with these requirement modifications the project was successfully completed without a corresponding shift in schedule thanks to the close communication and partnership between the Federal and Shell teams.

Subsea components are engineered to the highest standards.

Dedicated professionals assure all project expectations are achieved.

## Driving Forward

As a leading provider of specialty pipe connectors and flanges for both subsea and topside applications, Federal continually invests in its manufacturing and intellectual capabilities to ensure it keeps pace with the ever-increasing demands of the industry. We work hand in hand with our customers to deliver solutions whether it is for a high pressure, harsh environment application or custom-engineered components with a tight deadline.

Federal is proud to be a part of the Shell Perdido success story and we look forward to being a part of many such successes in the future.

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SERVICE THAT CONNECTS.

**Federal Flange, Inc.**
4014 Pinemont Drive
Houston, TX. 77018
Tel: 800-231-0150
www.federalconnects.com

# FMC TECHNOLOGIES SETS THE GLOBAL STANDARD FOR ADVANCED SUBSEA TECHNOLOGY

Shell's Perdido project is FMC Technologies' second full field development utilizing subsea oil and gas separation and boosting following the contract to supply trees and other equipment for Shell's Parque das Conchas (formerly called BC-10) deepwater project offshore Brazil. Parque das Conchas is the first full field development utilizing subsea oil and gas separation and subsea pumping in Brazil. A number of new and advanced technologies and innovations were designed by FMC to meet Parque das Conchas' numerous challenges. Many of those technologies are deployed in Shell's Perdido field.

"Shell wanted to exploit subsea heavy oil reserves," said Brad Beitler, FMC's Vice President of Technology, explaining the similarities of the Perdido and Parque das Conchas fields. "Shell had experience with submersible pumps but not with seabed pumps.

"Shell designed the systems and we worked with them as an alliance partner."

A caisson separator being deployed in the Gulf of Mexico.

FMC's scope of work for Perdido included the supply of 17 subsea trees, two subsea manifolds, five subsea caisson separation and boosting systems, topside and subsea controls, and related subsea equipment. The project utilized FMC's globally managed product standards, supporting manufacturing and supply networks and project management processes.

## Record-setting innovative enhanced vertical deepwater trees

The Perdido field includes 17 of FMC's Enhanced Vertical Deepwater Trees (EVDT) that provide added value by allowing customers to use the same standard tree design anywhere in the world. The added value brings versatility, installation savings and operational efficiency to ultra-deepwater fields. The EVDT earned FMC the 2008 Spotlight on Technology Award at that year's Offshore Technology Conference. The trees are rated for high pressure conditions up to 10,000 psi.

The EVDT system also enables deepwater completions from a small drilling rig containing only a surface blowout preventer (BOP). This capability allows operators to eliminate the need for expensive deepwater rigs with a subsea BOP, resulting in significant time and cost savings.

The EVDT was used to set a subsea deepwater completion record of 9,356 ft installed in Shell's Silvertip field, a part of the Perdido development. FMC set the previous water depth record of 8,995 ft, also in the Gulf of Mexico, in 2007. This record may be surpassed yet again during 2010 with a well planned for the Tobago field, also one of the fields feeding into the Perdido spar. This well would be in about 9,600 ft of water and will be completed using an EVDT system.

## Subsea separation and boosting system

The Perdido project contains five caisson separators that were installed on the seabed. This innovative system separates gas and liquids before the hydrocarbons are pumped back to the surface, enabling increased oil recovery by removing about 2,000 psi of back pressure from the wells.

"Gas flows up the riser while liquid is boosted by the electrical submersible pumps using multiphase separation," Beitler explained.

Utilizing the seabed separation system reduced the number of production risers to the spar to five, saving significant weight and cost.

FMC's subsea systems encompass a wide range of equipment and technologies to explore, drill and develop offshore oil and gas fields. Whether it's high-pressure/high-temperature (HP/HT) trees and wellheads, subsea controls and systems or production optimization services, FMC adds value to its customers throughout the life of the field.

FMC Technologies capitalized on the growing demand for deepwater oil and gas production with its subsea separation, boosting and processing systems. The company provides the technology to increase oil recovery for mature projects and develop new projects that may otherwise be considered economically unviable or inaccessible.

FMC Technologies

**FMC Technologies**
1803 Gears Rd., Houston TX 77067
Tel: 281 591 4000
Fax: 281 591 4102
Website: www.fmctechnologies.com

# FLEXIBILITY OF DEEPWATER CONSTRUCTION VESSELS EXPEDITES PERDIDO SPAR, FACILITIES INSTALLATION

## With its giant DCV *Balder* and SSCV *Thialf* heavy-lift/pipe lay vessels, Heerema Marine Constructors brings more certainty to Spar deployment in ultra-deep water

When Shell Exploration and Production drew up the logistics timetable for the record-setting installation in summer 2008 of the Perdido Regional Development Spar in the deepwater Gulf of Mexico (GOM), the company could not have accurately anticipated that pre-installation operations would be confronted by not one, but two major hurricanes and at least two significant tropical storms. Such unsettled weather could have increased the potential for significant delays.

Fortunately, this was not the case, thanks to significantly detailed pre-planning, including comprehensive probability estimates of weather contingencies. The flexibility available from the offshore heavy construction and pipe lay equipment was crucial to Perdido operations, including mooring system setup, installation of seafloor production piping and equipment, and float out and installation of the spar. This flexibility also was evident in placement of the spar's topsides and drilling and production equipment.

For that and other important reasons, Shell contracted early in the planning stages with Heerema Marine Constructors (HMC) for use of its Deepwater Construction Vessel (DCV) *Balder* and Semi Submersible Crane Vessel (SSCV) *Thialf*, along with a support vessel, the *M/V Union Manta*, for many of the never-before-attempted operations destined for Perdido.

### Setting the records

HMC's Perdido work scope included the following record-setting operations:

- Deepest ever installation of a spar in 7,820 ft (2,384m) of water.
- Installation of permanent suction mooring piles in world's record water depth of 8,360 ft (2,630 m).
- Installation of production flow lines and pipeline end structures in world's record water depth at 9,790 ft (2,984m).
- Installation of integrated topsides (new GOM record lift weight at 9,773 short tons (8,866 tonnes).

HMC also installed the spar's steel catenary export risers (SCR), water injection system, manifold piles and manifolds, electrical submersible pump (ESP) caissons and inlet assemblies.

Because it can marshal the world's largest dual-crane, heavy lift/pipe lay vessels to any offshore point in the world, HMC has been called upon for installation of more than half of all deepwater spars in the Gulf of Mexico alone. The *Balder* is adapted for deepwater pipe lay in the J-lay mode for installation of SCRs and flow lines. It also is equipped with the world's largest mooring line winch for the safe deployment of all known types of mooring lines, including those made of ultra long, large-diameter polyester fiber, such as those used at Perdido. Both the *Balder* and *Thialf* boast extremely powerful dynamic positioning (DP) systems for work in the hostile loop currents and eddies found in the GOM and elsewhere.

Installation of the Perdido spar was scheduled to take place during the summer 2008 Gulf hurricane season, which called for meticulous logistical planning and a firm interface among all parties involved, including a number of regulatory agencies.

The *Balder* was instrumental in ensuring that when floated out and upended, the Perdido spar hull could be brought to a "storm safe" mooring status in the shortest amount of time. This involved earlier installation of three of the mooring system's nine-point polyester lines. In fact, the installation sequences for the entire mooring system was optimized by use of a proprietary mooring line hook-up software.

Heerema Marine Contractors' semisubmersible crane vessel (SSCV) *Thialf* engaged in making Perdido spar's Quarters lift.

However, short delays were caused by approaching storms and tardiness in the spar's arrival at the Perdido site, so the flexibility afforded by the multifunctional construction vessel *Balder* allowed Shell and HMC to interrupt certain flow line and seafloor component installation operations to handle the spar when it did arrive.

### Paves way to higher safety awareness

The experience HMC has gained in installing deepwater floating production facilities shows that with the right equipment, the right tools and the right approach, critical installation windows, particularly for deepwater spar installation, can be minimized in duration and the associated risks actually reduced. The company's flexible, problem-solving approach actually strengthens its uncompromising attention to safety. This was made clear in the fact no HMC lost-time injuries were recorded during the entire Perdido installation sequence.

**Heerema Marine Contractors**
Vondellaan 55
2233 AA Leiden
The Netherlands
Tel: +31 (0)71 5799000
Fax: +31 (0)71 5799099
Email: info@hmc-heerema.com
Website: www.heerema.com

# RISER SYSTEM AT PERDIDO FEATURES NEWEST GE OIL & GAS TENSIONERS

## Top-tensioned production, drilling risers only alternative for record deepwater truss spar installation over DVA wells

In the post-Katrina/Rita Gulf of Mexico hurricane era, new met ocean criteria and acceptance requirements for "100-year and 1000 year" events calls for both new and improved elements to be incorporated into the design of deepwater drilling and production equipment.

Because the spar is the industry's deepwater and ultra-deepwater floating production platform of choice, new changes are being made in the tensioning and motion compensation hardware necessary to stabilize risers on spars against heavy storm wave and wind forces. One such progression involves the choice of ram-type, or "push-up" tensioners for top-tensioned vertical production and drilling/workover risers. Shell Exploration & Development's Perdido Regional Development Spar is equipped with this type of riser tensioning equipment supplied by GE Oil & Gas (formerly GE Vetco Gray).

From the beginning Shell, as operator for BP and Chevron, planned to employ a direct vertical access (DVA) configuration at the Perdido spar's host location in the Great White field in order to bring oil and natural gas production from the field's subsea wet tree wells to the spar's topsides for subsequent handling and export back to shore. This would be the first such DVA setup to be installed on a truss-type spar.

Top-tensioned risers were essential for the Perdido spar, at a record depth of some 7,820 ft (2,384m) from spar topsides to the sea floor. Buoyancy can tensioned risers employed on spar platforms in much shallower water would have been impracticable.

Additionally, instead of having a riser and dry tree for each well, the spar would be equipped with only six risers – five pipe-in-pipe risers for handling production from multiple subsea wells and one high-pressure riser for drilling and completions. Instead of being connected with individual wells, the production risers would be connected to five seafloor caisson/electric submersible pump (ESP) boosting stations that would handle flow from 22 subsea DVA wells and 11 subsea offset wells. In addition to increased efficiency due to lighter weight, having only six risers would help keep the spar's topsides decks smaller and thus, less capital intensive.

The single, high-pressure DVA drilling riser would be used to allow a topside-mounted rig to drill, complete and to perform interventions on wells at significantly lower cost than employing deepwater mobile rigs for such purposes. In addition, the topside rig would use this riser to gain access to the seafloor booster stations for possible change-out of ESP equipment, should that become necessary.


Perdido spar riser tensioners in various stages of installation prior to installation of the topsides. The six tensioners are in two rows in the center square of the spar deck. The three units on the bottom row are installed complete and stroked down (closed) awaiting commissioning. The remaining units on the top row are in various stages of installation.

### First offshore installation

Six GE Oil & Gas hydraulic/pneumatic tensioners were installed to support the risers aboard the Perdido spar. The installation was made at the spar's offshore site rather than the conventional installation at a shore base prior to float-out. This was the first time such a remote offshore ram riser tensioner installation has been made.

In general, riser tensioners are designed to provide the necessary interface to support riser weight and to compensate for relative motion due to spar offset, heave, thermal expansion, payload changes and subsidence. A typical MODU drilling riser tensioner consists of a hydraulic cylinder with sheaves at both ends. The cylinder is connected to a number of high-pressure gas bottles, or accumulators, via a medium separator. A wire rope is rigged in the cylinder with one end

An assembled Perdido riser tensioner during factory acceptance testing, partially stroked out, but without the accumulators.

connected to the fixed part of the tensioner and the other end is connected to the riser.

Top-tensioned risers connected directly to the spar hull provide a range of stiffness at the hang-off point. This stiffness variation provides a tradeoff between riser stroke relative to the hull and the tension on the riser, and combined with lower operating costs, are the practical alternative to buoyancy can-supported riser systems.

The GE Oil & Gas ram-type riser tensioner configuration uses multiple (four) hydro-pneumatic compression cylinders that employ efficient, low-fluid volume to allow for large internal accumulator volumes that, depending upon the application, minimize the requirement for external accumulators while providing for the required range of stiffness. Combined with durable construction and relative low accumulator pressures, the GE Oil & Gas tensioners help reduce risk elements and increase tensioner life. Being small in footprint versus their capacity, they also allow for more available topsides deck space.

Each of the GE Oil & Gas tensioners is equipped with four hydro-pneumatic cylinders, each operating independent of the other but combined, constitute a "team.". Should trouble be experienced with any one cylinder, it can be easily removed and either repaired at the site or sent to shore. Meanwhile, as evidenced by testing under load at GE's Houston manufacturing center, the remaining three cylinders are capable of holding sufficient tension to continue required motion compensation.

## Coating reliability enhanced

To help meet Shell's 25-year lifespan design requirement and provide high reliability in a corrosive environment, the rods of the Perdido spar riser tensioners are protected with a newly developed coating that virtually eliminates the threat of degradation by acids contained in oilfield chemicals.

Tensioner pressure feedback is monitored and adjusted with equipment located in the Spar topsides control room.

Significant to its continued innovation and development of new hardware, GE Oil & Gas riser tensioner technology was a finalist for the Woelfel Best Mechanical Engineering Achievement Award at the 2009 Offshore Technology Conference.

GE Oil & Gas

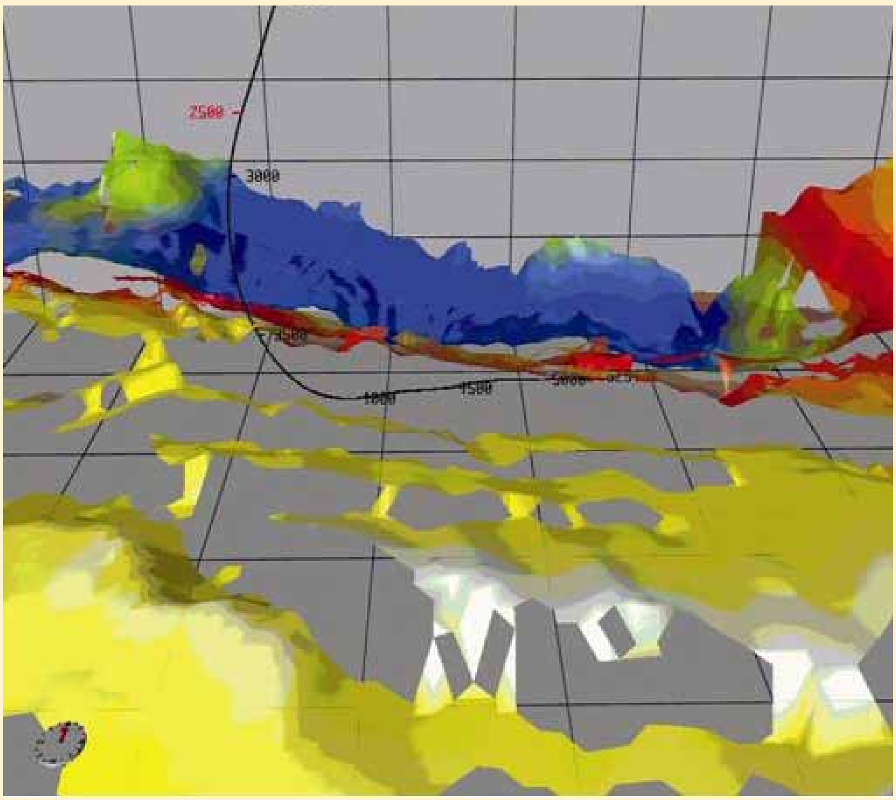
**GE Oil & Gas**
4424 W. Sam Houston Parkway North
Suite 100
Houston, Texas 77041
Tel: 281-448-4410
Website: www.geoilandgas.com

# HALLIBURTON PROVIDING LIFE-OF-FIELD SOLUTIONS FOR SHELL PERDIDO

The Shell Perdido project represents an industry milestone in overcoming the technology challenges of ultra-deep waters, subsalt drilling, and complex completions under extreme downhole conditions. Halliburton has been associated with Shell's deepwater Gulf of Mexico projects since the Cognac field in 1979 and has been an integral part of the Perdido successes since its earliest phases, providing drilling, cementing, permanent monitoring, and chemical injection solutions.

## Comprehensive Drilling Services

Halliburton's involvement in the Perdido project began in 1999 during the early exploration of the Great White field. In 2006, Halliburton began drilling "batch-set" wells for the Perdido spar, providing Sperry performance mud motors and basic LWD services. Subsequently, Halliburton deepened some of the batch- set wells and used the Geo-Pilot® rotary steerable system with the GeoTap® LWD formation tester to help evaluate the compartmentalized formations in real time. Halliburton also drilled horizontal wells in the Silvertip field using all the basic services plus StrataSteer® 3D Geosteering Service and InSite ADR™ Azimuthal Deep Resistivity Sensor to optimize wellbore placement. This stage of the project was completed in October 2009. Based on the value Shell and the Perdido team gained from the application of these advanced technologies and enhanced personnel experience, Halliburton was awarded subsequent drilling services work for the spar and subsea wells. Drilling for the infield subsea wells will begin in April 2010 and drilling for spar should begin in June.




Halliburton has drilled "batch-set" wells as well as horizontal wells with geosteering for the Perdido project.

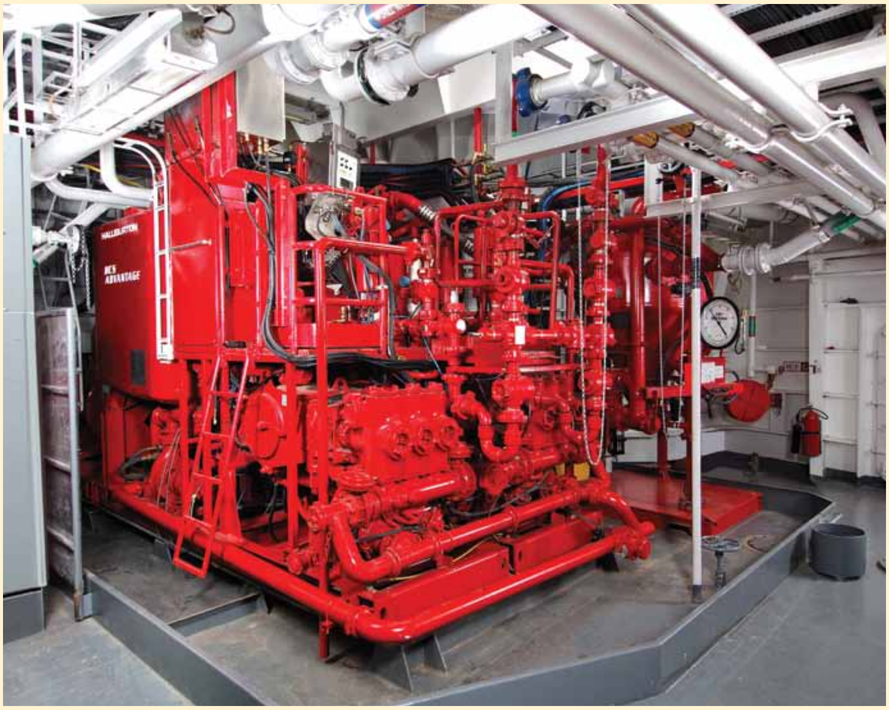
## Cementing Services with Zero NPT

Halliburton completed Shell's batch-set project within the specified time window, delivering maximum efficiency without sacrificing quality. This included the installation on the rig of a steady flow bin, continuous metering system, 150-bbl batch mixer and Halliburton's state-of-the-art HCS Advantage™ cementing skid for cementing operations and well control contingencies.

Halliburton used two-man crew teams to ensure continuous cementing operations with coordination through its facility in Alaminos Canyon. The key to helping improve the probability of getting cement slurry to seabed was the ZoneSeal® Isolation Process, an automated control system for foam cementing services. By using a fully automated nitrogen unit, the cementing crew was able to foam the standard Type-1 cement before injection of the unfoamed tail slurry. For some wells, the spacer was also foamed to increase the sweeping efficiency, reducing hydrostatic pressure and assisting successful placement of foamed lead and conventional tail slurry. On inner-string cementing jobs, a drill pipe dart was released and latched into the float shoe to help address cement slurry residue/ contamination on the walls of the drill pipe. In total, Halliburton batch-set 23 wells by mixing and pumping 96,000 sacks of cement in an offshore environment of over 8,500-ft water depth. In all, this was a very successful cementing operation with zero NPT related to the cementing operations.

## Permanent Monitoring and Chemical Injection

Halliburton WellDynamics has supplied Shell with permanent monitoring and chemical injection systems for their subsea installations since the mid-1990s. Due to the reliability

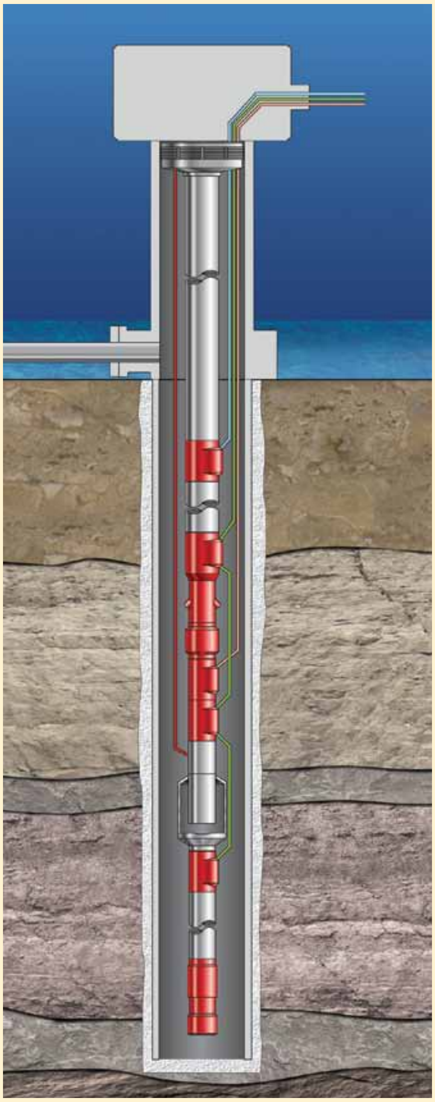


Halliburton's HCS Advantage™ cementing skid aboard the Perdido Spar.

and success of these previous installations, Halliburton won the contract to supply the permanent monitoring and chemical injection systems for the Perdido project.

Conventional subsea completions, which are to be completed from both the Perdido spar and mobile offshore drilling units, consist of 20 Kpsi ROC™ series dual-quartz gauge assemblies, shallow and deep-set chemical injection systems, and multi-line spooling services. All equipment was manufactured to meet Shell's specific material requirements for the Perdido project. As part of the systems approach to the installation of permanent monitoring systems, Halliburton WellDynamics also supplied and installed the electrical feed-through systems for the FMC direct vertical access subsea wellhead systems. This was the first installation of this feed-through system design in the Gulf of Mexico and the installation process ensured that multiple checks were carried out on the wellhead systems between installation and subsea deployment to confirm they were fit for purpose. The first successful subsea installation on a satellite subsea well was completed in October 2008 and the equipment installed is designed to supply downhole pressure and temperature data for the life of the wells.

Since the Perdido project has low energy reservoirs, subsea separating and boosting systems (SBS) are installed on the Perdido Spar to lift the hydrocarbons to the surface. As part of this SBS system, Halliburton WellDynamics installed three specially calibrated ROC series gauges in the lower completion to allow real-time measurements of fluid levels. These fluid measurements are used to ensure optimum fluid levels at the electrical submersible pump (ESP), and therefore, extend the life of operation before a workover is required. Along with the fluid level measurements, Halliburton WellDynamics supplied multiple chemical injection systems and multi-line spooling services. During the first two SBS installations, changes were made to the installation process and equipment resulting in a substantial reduction in the installation time of the systems. Plans are to provide additional subsea installations and SBS systems.



Halliburton WellDynamics SBS Level Monitoring System

## Continued Commitment

Halliburton will continue to provide the full extent of oilfield services for the Perdido project through all its phases and is Shell's willing partner as we extend the search for oil and gas to future frontiers in the Gulf of Mexico and around the world.

HALLIBURTON

**Halliburton**
10200 Bellaire Blvd., Houston, TX 77072
Tel: 281.575.3000
Website: www.halliburton.com

# HORNBECK OFFSHORE SHELTERED SOME OF PERDIDO'S MOST VALUABLE ASSETS

As many as 220 people per shift came to work aboard the Perdido deepwater spar during the peak of commissioning and hookup, but it was a short commute – they all lived next door.

Their offshore home was the *HOS Achiever*, a new 430-foot, third-generation dynamically-positioned (DP) multi-purpose support vessel (MPSV) that Hornbeck Offshore (NYSE:HOS) had turned into a floating hotel.

"The workers called it their flotel," says Ben Todd, Vice President of Hornbeck Offshore's MPSV and Specialty OSV Fleet. "When Shell came to us in 2008, no vessel in the area met Shell's needs for its offshore workforce."

The multi-purpose DP-3 *HOS Achiever* certainly was large enough for the job, but not set up for as many guests as Shell required; so in early 2009, Hornbeck spent six weeks reconfiguring the vessel to accommodate 283 passengers and crew. Additional galleys, lounges and sleeping quarters were added, with common areas including wireless internet service, satellite TV and sat-phones available any time.

Not only did the workers need a comfortable place to live, they and their gear had to be lifted safely across open water back and forth from the spar each day. During the *HOS Achiever*'s 244 continuous service days in the field, there were more than 47,300 personnel transfers between the vessel and the spar. At the peak of activity, the *HOS Achiever* also received as many as three of the big Sikorsky S-92 helicopters a day.

"Shell really supported us on the inhabitability of the vessel," Todd says. "Shell's people participated in the design and layout of the additional mess rooms and galleys, and the deck where we did the personnel transfers. A lot of thought went into all of that, and it made for a very smooth evolution."

For more than eight months, the 430-foot DP-3 *HOS Achiever* MPSV served as Perdido's floating hotel.

## A logistics challenge

Working on the spar, in transit, or asleep in their room on the ship, the safety and comfort of every person was accounted for at all times. Hornbeck's onboard staff even tracked those who had rotated home, to make sure there was a bed available on the *HOS Achiever* when they returned.

"We had 25 crew members for the vessel and another 28 catering and hotel staff on board," Todd says. "While our marine crew was responsible for vessel operation and vessel safety, the rest of the staff cooked, cleaned, made up rooms and washed clothes, so that Shell's team could focus on their jobs."

Industrial-strength trash compactors minimized the volume of solid waste until it could be taken to an onshore landfill. Reverse-osmosis filters purified seawater to supply all of the ship's water for drinking and bathing.

"Over the course of the Perdido project, we received more than 1 million gallons of fuel for consumption by the *HOS Achiever* with no environmental incidents," Todd says.

## Safety success

The *HOS Achiever* began it's transformation from MPSV to a floating hotel in February 2009. It was deployed to Perdido on April 16, and maintained station alongside the spar on continuous DP operations 24 hours a day for more than eight months with no downtime or operational interruptions. By the time the *HOS Achiever* and its crew left the field in mid-December, the vessel had logged nearly 184,000 work hours without a recordable incident.

"From the beginning, our primary concern was safety," Todd notes. "A lot of the contractors were not accustomed to working on vessels, so we had to orient them to the hazards of working in a marine environment. Many workers came from shipyards, with limited experience offshore. With Shell's help, all of the contractors completed orientation and training programs before going to the spar, so everyone knew what to expect."

Dale Norman, Shell Construction team flotel lead for the Perdido project, commented, "Hornbeck Offshore's ability to provide reliable and safe performance in supporting Perdido with the *HOS Achiever* made a significant contribution to the overall success of Shell's global 'Goal Zero' safety program."

## About HOS

Through its fleet of over 80 vessels, Hornbeck Offshore provides technologically-advanced marine services for some of the energy industry's most demanding projects. The 66-acre HOS Port marine base in Port Fourchon, Louisiana, includes nearly 3,000 linear feet of dock space. From there, HOS vessels provide logistical support for drilling, production and construction operations throughout the Gulf of Mexico. Elsewhere, HOS vessels are working for select upstream and downstream customers along the East and West Coasts of the United States, the Great Lakes, Puerto Rico, Mexico, Brazil, Trinidad and Qatar.

In January, 2010, Ben Todd, Vice President of Hornbeck Offshore's MPSV and Specialty OSV Fleet (left) accepted an award for outstanding safety performance from Dale Norman, Shell's Construction team flotel lead for the Perdido project.

Cranes aboard the 430-foot DP-3 *HOS Iron Horse* MPSV can lift up to 400 tons of cargo.

The 260-foot DP-2 *BJ Blue Ray* is a new breed of deepwater OSV well-stimulation vessel.

HOS operates some of the world's most advanced offshore service vessels.

**HORNBECK OFFSHORE**
*Service with Energy®*

HOS

103 Northpark Boulevard, Suite 300
Covington, LA 70433
Tel: 985-727-2000 • Fax: 985-727-2006
Website: www.hornbeckoffshore.com

# H&PS RIG 205 READY FOR PERDIDO SPAR DRILLING, COMPLETIONS, INTERVENTIONS

## With special modifications, 20,000-ft SCR rig to tackle subsea wells located in up to 9,627 feet of water

When Shell Exploration and Production Co., as operator for the Perdido Regional Development Spar, decided to contract for a small-footprint, fit-for-purpose drilling rig in order to access 35 existing wells connected to the spar as well as to drill as many as nine additional wells from the spar itself, it chose Helmerich & Payne, Inc. (H&P), Tulsa, for the job.

With nearly four decades of platform drilling experience and more than two decades of experience working for Shell on a number of fixed and floating platforms both in the Gulf of Mexico and overseas, H&P assigned its Platform Rig 205 for the Perdido spar.

The self-erecting rig was modified for drilling, completions and well interventions specifically from a truss spar, and was mobilized to Perdido in summer, 2009. No stranger to drilling from both fixed and floating production facilities, H&P built Rig 205 in 2002. It was then used by Shell on its Cognac fixed and Ram Powell tension-leg platforms (TLP), both located in the deepwater Gulf.

### Rig upgraded for spar topsides

According to Rig 205 superintendent Tom Freeny, the rig was upgraded due to the increased motion and acceleration forces affecting the Perdido spar, which is anchored in some 8,000 ft (2,383 m) of water. The rig's drilling module is supported by a custom skid base that spans the spar's 65-ft (19.8 m) capping beams and is designed to be assembled by the spar's two pedestal cranes.

Rig 205 also has been upgraded in a number of other areas, Freeny said. These include draw works disc brakes, a 49-½-in. rotary table with PS-21 slips, a "Cyclone" Iron Roughneck, and a 16-¾-in. x 5,000-psi BOP with setback dolly positioning, among others.

"Interfacing with Shell was required for installing and tying down several individual support packages," he pointed out. These included a pipe rack module, with engines and the SCR house; a porch for the third mud pump, P-tanks, a diesel tank and four auxiliary mud tanks, among other attributes.

Helmerich & Payne's offshore Rig 205 rests tightly atop the Perdido Spar.

Considerations for the design of a more robust hurricane tie-down system included anticipated spar accelerations due to high winds and sea states, said Freeny. For increased safety and environmental protection, the rig also features beefed-up systems for handling increased hook load and setback, as well as more user-friendly rig floor equipment to eliminate manual torque wrenches, hammers, etc.

The Perdido spar features the first application of wet tree, direct vertical access (DVA) wells from a spar-type floating production system. It is fitted with a single high-pressure drilling and completion riser suspended from the topsides for access to the 34 subsea trees, 22 of them located directly below the structure. This configuration will allow Rig 205 to use a surface blowout preventer (BOP) to drill, complete and later sidetrack those and subsequent individually drilled wells to 19,000 ft (5,795 m) or more.

Because the DVA configuration permits the rig to access a larger number of subsea completions, Shell anticipates the benefit of significant drilling and completions savings without loss of rig flexibility.

The rig also is equipped to install and intervene on the five electric submersible pumps contained in seafloor caissons that are used for the spar's subsea separation and boosting system.

### Close cooperation pays off

Freeny and his Rig Managers, Jimmy Welch and Tony Miller, were included in both preliminary planning and actual topsides design meetings by Shell, he said.

"It became necessary to add some unique features to the rig to meet Shell's requirements," said Freeny. "Without constant communications between both companies, working together as a cohesive team, there could have been delays. As it was, the rig was modified and ready for mobilization to the spar at the appointed time."

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**Helmerich & Payne, Inc.**
1437 South Boulder Ave., Tulsa, Oklahoma 74119
Tel: (918) 742-5531
Fax: (918) 742-0237
Website: www.hpinc.com

# KIEWIT OFFSHORE SERVICES' EXPERIENCE AND "NO SURPRISES" APPROACH RESULTS IN QUALITY SERVICES FOR THE OFFSHORE OIL AND GAS INDUSTRY

KOS' extensive experience in fabricating large, complex topsides enabled the company to meet the challenges associated with the multi-discipline Perdido Project. KOS' topsides scope required the installation of 82,000 linear ft of piping, and over 800,000 linear ft of electrical cable. In addition, KOS fabricated 1,500 tons of skidshoes to support the structure during the construction, loadout and transportation phases. The 10,000 ton structure was completed in 24 months.

The fabrication sequence for constructing the topsides was designed to permit all craft disciplines to start work as early as possible, optimizing the number of craft on each component of the Perdido Project. The topsides were fabricated in three major sub-assemblies, or deck levels, and lifted into position using heavy lift cranes. The largest of these sub-assemblies weighed over 1,300 short tons and was lifted into place using twelve crawler cranes.

In addition to the Perdido topside fabrication, KOS facilitated the outfitting of the 22,000 ton spar hull for offshore installation. Utilizing KOS' deep hole, the spar was offloaded from the heavy lift transport vessel, grillage and supports removed, motion dampening strakes installed and a dead weight survey conducted.

KOS' third scope in the Perdido Project was the drill rig refurbishment, where the company focused on upgrading an existing rig's capacity and equipment, as well as updating its hurricane tie down requirements. After pieces of the drill rig arrived at KOS, they were further dismantled and reconditioned. These components were assembled into modules and the drill rig was stacked, commissioned and function tested.

Perdido topside lift and spar hull at the KOS fabrication facility.

Once testing was complete, the drill rig was dismantled, loaded out and shipped offshore to the spar hull.

KOS and its subcontractors worked over 2 million manhours on the Perdido Project, completing the job with only two incidents. As an OSHA Voluntary Protection Program (VPP) site, KOS is recognized as having one of the safest yards in the industry. It's not just the company's safety practices that make KOS stand alone, but the facility itself is truly impressive. Accessible by highway, rail and water, the KOS fabrication facility boasts more than 2,900 linear ft of high-capacity bulkhead. Water depths along the bulkhead range from 25-55 ft with the entire length supported by a continuous-pile-founded relieving platform. This allows for the docking of several large scale projects at the same time. For heavy lift vessel projects such as Perdido, KOS has a deep hole with water depths up to 78 ft. The facility also has unimpeded access to the Gulf of Mexico through the Corpus Christi and La Quinta shipping channels, and boasts the world's only Heavy Lifting Device capable of lifting up to 13,000 tons. Projects like Perdido are executed successfully due to the extensive

The Perdido topside loadout at KOS' facility.

resources available at KOS and the talented people building them.

No job is too large or too complex for this leading fabricator for the oil and gas industry. KOS takes a "no surprises" approach to every project, enabling the company to plan ahead and mitigate risks. This mentality, coupled with their state-of-the-art facility, has enabled KOS to help its clients build the industry's most well known projects such as Perdido.

Kiewit

**Kiewit Offshore Services**
2440 Kiewit Road, Ingleside, Texas 78362
Tel: 361-775-4300, Fax: 361-775-4433
Website: www.kiewit.com

# NOBLE CORP.'S INNOVATIVE ENGINEERING HELPS SHELL TO DEVELOP PERDIDO

Long before the industry dared to dream that operating in the ultra-deepwater of the U.S. Gulf of Mexico could be possible, Noble took a bold and pioneering step in that direction. Believing that the deepwater was the future, the Company undertook the conversion of several shallow water submersibles into semisubmersibles known as the "EVAs." The EVAs, which stood for "economic value advantage" leveraged Noble's considerable engineering expertise and well-deserved reputation for efficient and safe operations.

The EVA rigs immediately demonstrated why they were so named. Several set water depth records. If there was any skepticism in the offshore drilling industry that a converted submersible could begin a new life capable of drilling in 7,000-8,000 ft of water, it was quickly swept away. One of the forward-thinking oil companies that contracted an EVA semisubmersible early on was Shell, beginning a15-year (and counting) partnership of continued innovation in the industry.

More recently, Shell contracted another one of Noble's new ultra-deepwater semisubmersibles, the *Noble Clyde Boudreaux*, to batch drill 23 wells in water depths ranging from 7,800-9,000 ft of water for its innovative ultra-deepwater Perdido development project.

## Upgrade project

The *Noble Clyde Boudreaux* began life as a Russian-built hull that Noble had purchased. The hull was completely stripped of all of its original drilling equipment, offering Noble and Shell a clean slate that eventually became one of the largest and most technologically advanced drilling rigs in the Gulf of Mexico.

The rig was outfitted with the latest automated drilling and pipe handling equipment designed to take rig workers out of harm's way and to increase performance while saving time. This upgrade included an automated pipe racking system and two iron roughnecks.

The *Noble Clyde Boudreaux* batch drilled 23 wells for Shell's Perdido development project while moored in water depths up to 9,000 ft.

## Upgraded mooring system

The *Noble Clyde Boudreaux* originally was designed to have a standard 8-point mooring system but after Hurricanes Katrina and Rita devastated the Gulf drilling industry with Category 5 winds, Noble conducted studies to make the rig capable of withstanding a 100 year storm.

"With participation from Shell, we redesigned the mooring system to a 16-point system based on the results of the studies," said Dave Petitjean, Noble's Project Manager during the rig's upgrade. "We also redesigned it to be a larger and more robust system."

The mooring wire was increased to 3 ¾-in. diameter from 3 ⅛-in. diameter for greater breaking strength. Likewise, the chain was increased to 3 ¼-in. from 2 ¾-in. Finally, the size and weight of the anchors were upgraded to 18 metric tons from 12 metric tons. Shell employed a suction pile system for the Perdido wells so the larger anchors were not used during the project.

In order to accommodate the extra weight of the larger chain and wire rope and the 16 mooring winches, the rig was made more buoyant by the addition of smaller columns to each of the four corner columns and "blisters" to each pontoon.

## Safety first

While the *Noble Clyde Boudreaux* was drilling the Perdido wells, it received the U.S. Minerals Management Service's (MMS) Lake Jackson District SAFE (Safety Award for Excellence) Award for 2007 and 2009. The rig was delivered in June 2007, and during the first year of working for Shell on Perdido, the rig completed the year with 1,086 days without a recordable or lost-time incident. The rig was visited and inspected nine times by the MMS during its first year of operations, with no non-compliance issues reported.

Noble Corporation's innovation and commitment to safety has helped Shell to successfully complete the Perdido project, itself an innovative endeavor. These attributes have helped to build Noble into one of the world's largest offshore drilling contractors capable of handling the most complex projects around the world with extra value added.

NOBLE

**Noble Drilling Services Inc.**
13135 South Dairy Ashford, Suite 800
Sugar Land, TX 77478
Tel: 1-281-276-6100 • Fax: 1-281-491-2092
Website: www.noblecorp.com

# THE BAYOU COMPANIES PROVIDE WELDING, COATING AND INSULATION SERVICES AROUND THE WORLD

Straight on the heels of successfully fabricating and supplying pipe line end terminals (PLET) for Shell's Ursa/Princess waterflood project, Bayou Welding Works (BWW), a subsidiary of The Bayou Companies Inc. (TBC), was awarded a contract to fabricate 14 additional PLETs for Shell's Perdido development. The Perdido PLETs are installed in nearly 10,000 ft of water, making them some of the deepest in the world.

The Ursa/Princess project saw the first use of the technology of another Bayou Companies subsidiary, Commercial Coating Services International (CCSI). CCSI's internal fusion bond epoxy (FBE) InnerGard™ coating improves the flow of water, oil and natural gas by creating a smooth, defect-free surface. The company constructed a new coating plant specifically to apply internal FBE for the Ursa/Princess water injection lines. This new facility also was used to internally coat the flowlines and pipelines supplied to the Perdido project.

The first load out of PLETs and other flowline and pipelines were completed on schedule while the second load out was completed ahead of schedule with no lost-time incidents. Among the welds and coating provided by TBC were double joint welding to combine two 40 ft joints prior to coating operations, FBE coating, triple layer polyethylene (TLPE) coating to provide abrasion and corrosion protection for pipes contacting the seabed, glass syntactic polyurethane (GSPU) coating of line pipe, forging production welding of end pieces for installation and forging collar coating.

The steel catenary risers were counter bored at the end of each pipe to provide a smooth ID. A total of 1,108 joints of 10-in. and 16-in. pipe were counter-bored for a total of 2,216 bores.

## Full array of services

The Bayou Companies was established in 1942 as a one-man, one-welding truck operation and has grown to provide welding and coating services to the some of the largest offshore oil and gas production projects in the world. Today, the company provides a full array of welding and coating services, including pipe multi-jointing, pipe-in-pipe fabrication and insertion, and steel catenary riser, flowline welding and flow assurance insulation products.

The company has provided fusion bond epoxy coatings for more than 40 years and today operates multiple FBE operations locations in Louisiana, Texas, California and Canada. The facilities can handle pipe diameters from 2-in. to 60-in. and up to 80 ft in length. TBC provides ID coating services for a smooth, defect-free surface at facilities in Louisiana, Texas and Canada, and can accommodate 2-in. to 48-in. diameter pipe in varying lengths. CCSI, which provided its InnerGard ID FBE coating, operates facilities in Louisiana, Texas and California.

In addition to providing PLETs, PLEMS, manifolds and jumpers, BWW also offers new offshore platform fabrication, production packages, living quarters and heliports. The company's onshore fabrication facilities include a waterfront capable of handling up to a 100 ft x 400 ft barge, 10,000 sq ft of covered storage area, and 90 ft x 150 ft and 50 ft x 150 ft fabrication shops equipped with overhead cranes. Bayou Companies' port of Iberia facility offers more than 280 acres of storage and access to the Intracoastal Waterway and the Gulf of Mexico with 6,000 linear ft of waterfront. The facility also features a 250 ton and 70 ton crawler cranes, a 70 ton cherry picker and the capacity to load more than 20 89 ft flat railcars within the facility.

Perdido PLET sled S-2 and a double-jointed flowline with FBE and GSPU coating loaded to barge.

The PLETs for Perdido being loaded to barge at Bayou's waterfront facility.

The Bayou Companies strives to continually improve workplace safety and operations in order to provide quality products and services in an environmentally friendly manner. The company's Quality Management System is in accordance with the requirements of ISO 9001:2008, ISO 14001:2004 and OSHAS 18001:1999.

It is The Bayou Companies' extensive experience and expertise and its commitment to quality products and services that has resulted in large and small oil and natural gas companies around the world to choose the company for their pipeline and flowline welding and coating requirements.

**The Bayou Companies, Inc.**
5200 Curtis Lane
New Iberia, LA 70560
Tel: 1.800.619.4807 or 337.369.3761
Fax: 337.365.9747
Website: www.bayoucompanies.com

# OCEANEERING INSTALLS RECORD DIVERLESS DEEPWATER HOOPS TIE-IN

The Oceaneering International, Inc. *Olympic Intervention IV* vessel working near the Shell Peridido spar. Shell and Oceaneering have a long-standing relationship that has achieved excellent results in subsea projects in the Gulf of Mexico and other deepwater regions throughout the world.

Who would cut a perfectly good pipeline? Oceaneering worked with Shell to add a new tie-in for the Perdido oil export pipeline to the currently operating Hoover Offshore Oil Pipeline System (HOOPS) pipeline. This is the first time in deepwater operations anywhere in the world that a flowing pipeline without a pre-existing connection has been shut-in and re-configured to tie-in a new pipeline.

The installation took place as the result of the partnership between Shell's design team and Oceaneering's installation team. Contributing to the remarkable success story were Oceaneering's high-technology *Olympic Intervention IV* support vessel, remotely operated vehicles (ROVs), ROV simulation capabilities, and a diverless installation team that worked in concert to achieve the desired results with only a short, 17-day interruption of downstream production of the HOOPS pipeline.

## Tie-in Concept

The Perdido host facility operates in ultra-deep waters of the Alaminos Canyon Block 857 that had no production export infrastructure. The closest tie-in opportunity was at HOOPS, which extends from the ExxonMobil Hoover platform to Freeport, Texas. HOOPS did not have a connection link so it was necessary to perform the deepwater installation of a connection point to a working pipeline with minimal production shut in. Based on its experience with the repair of the Mars pipeline after Hurricane Katrina, Shell designed the hardware and a subsea process for the Perdido tie-in. Oceaneering facilitated Shell's design feasibility using diverless intervention with ROVs.

Oceaneering's scope for the tie-in consisted of fabricating and assembling the subsea hardware components, then performing system integration, operations planning, simulation, and subsea execution in 4500 fsw. Oceaneering's Deepwater Technical Solutions (DTS) group developed many of the cleaning, clamping and cutting tools used in the Perdido operation.

## Mission Simulation

Oceaneering used their onshore ROV simulator system to perform the preinstallation sequence. This process allowed the ROV pilots to become familiar with the tools they would be using and to practice installation procedures under true subsea conditions. Once the installation vessel mobilized, a portable ROV simulator system was used offshore on the job.

## *Olympic Intervention IV* Vessel

The 312-ft *Olympic Intervention IV* subsea support vessel and crew performed the installation using built-in dual Millennium® Plus ROVs. The *Olympic Intervention IV* features a

150-mt active heave compensated crane that was used for overboarding the connection equipment. The vessel transmitted streaming video for real-time work observation by shore personnel during the job. The heave-compensated ROV launch and recovery system onboard the *Olympic Intervention IV* lowered the ROVs from the surface and transported the specialized tooling required for the job.

## ROV Operation

The two separate ROV systems were staffed with multiple crews for 24-hour operations and were utilized for around-the-clock subsea work. The two systems usually worked together to complete the required tasks. In many cases, one ROV would perform the work while the second ROV directed the task from a better position near the worksite. High-definition cameras allowed the pilots to view the hardware in finer detail than possible with conventional filming technology.

## Subsea Execution

The Perdido tie-in was accomplished using an innovative 70-ft long, 14-ft high, 50-ton foundation, which served as a structural support and work table that provided the means to align the pipeline connection. The foundation remains in place on the sea floor, where it can be used for future repair and maintenance operations.

Two lift frames were used to raise the 18-in pipeline about 3 ft off the seabed. Using winches and buoyancy gauged to 60,000 lb, Oceaneering's crew pulled the foundation into place between the lift frames. With the foundation in place, Oceaneering used an ROV-operated Fusion Bond Epoxy (FBE) and weld seam removal tool to clean the existing HOOPS pipe and prepare it for connector installation. The pipeline was then sealed off locally on each side using isotope-embedded pigs. An ROV verified the pig locations before a 28-ft section of pipe was cut and removed. Spool assemblies were then landed onto the foundation, rolled into place and connected to the pipelines, leaving vertical hubs to re-connect the existing pipeline via a pre-fabricated jumper and an additional hub to connect the Perdido Oil Export pipeline.

Oceaneering lifting the dual-hub connection assembly using the 150-mt active heave-compensated crane on the deck of the *Olympic Intervention IV.*

## Success Story with No Ending

The HOOPs tie-in is only one of Oceaneering's success stories for Perdido and many other deepwater projects. Whenever or wherever there is a challenging subsea opportunity, Oceaneering is always available with its intervention expertise and experience.

The weld seam and Fusion Bond Epoxy (FBE) removal tool used subsea to prepare the HOOPS pipeline for adding a tie-in connection. Photo courtesy of Shell

Two Millennium® Plus ROVs work in tandem to check pipeline ovality prior to pipeline cutting operations.

Millennium® Plus ROV surveys the completed jumper installation and subsea tie-in at 4500 fsw.

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**Oceaneering International, Inc.**
11911 FM 529, Houston, Texas 77041 U.S.A.
Tel: +1 (713) 329-4568
Fax: +1 (713) 329-4951
Website: www.oceaneering.com

# SCHLUMBERGER PIONEERS RECORD DEEPWATER OPEN-HOLE GRAVEL PACK COMPLETIONS

Two extremes define Perdido's early development wells: The water is very deep, and the reservoirs are very shallow below the mudline. The difficulty for drillers is the small difference between the amount of pressure required to control the wellbore and the amount of pressure required to fracture the rock around it.

In the Silvertip field, where Schlumberger completed Perdido's first two development wells, the narrow pressure window is so low that conventional open-hole gravel pack treatments would be at risk.

"The challenge is to pump the gravel slurry at a low enough pressure to keep it from fracturing and entering the formation, without reducing the effectiveness of the gravel placement," says Salah Al-Harthy, Schlumberger well completion engineer. "The efficiency of the gravel pack directly affects the productive life of an open hole well. Any voids will expose the screens to erosion and possible well failure."

Perdido's first two development wells were drilled from a floating rig in the Silvertip field, in 9,400 feet of water. The targeted zone was the Oligocene-Frio sands, a portion of the Lower Tertiary that consists of as many as six separate reservoirs from 1,500 to 2,500 feet below the mudline.

The wells reached a maximum total depth of 16,513 feet, with horizontal open-hole length of 2,300 feet. Since the Oligocene-Frio sands may compact as they are produced, well planners decided to complete these sands with a horizontal open-hole gravel pack to enhance the longevity of these completions in a highly compressive reservoir.

"There were two primary challenges in completing these sands with horizontal open-hole gravel packs," Al-Harthy says. "The first challenge was the narrow pressure window and the second challenge was the selection of carrier fluid."

## Designing the completions

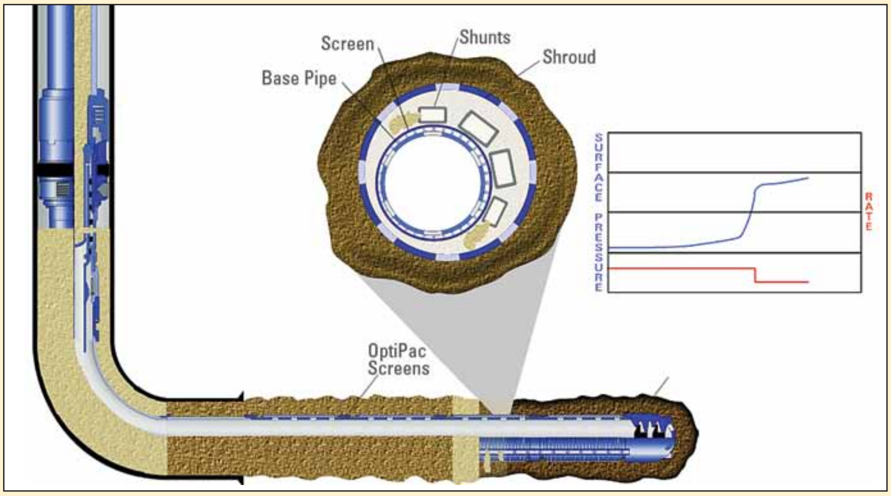
The fracture gradient of the targeted Oligocene-Frio sands was about 7,100 psi. With reservoir pressures of 6,700 psi, that meant the pressure window for placing the gravel pack was only 400 psi. The risk of such a narrow operating window is that the reservoir rock can fracture during treatment, causing premature screen-out and insufficient packing around the screens.

The requirement for the gravel packing carrier fluid needed to have enough carrying capacity to suspend the gravel and remove the filter cake after the gravel was placed. It also needed to have a low corrosion rate around the sand control screens, since the wells were being completed more than a year before first oil.

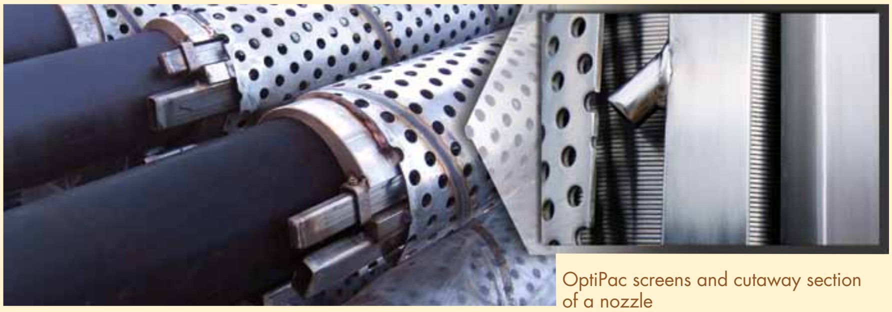
To overcome these challenges, Schlumberger used two of its flagship technologies, the OptiPac* Alternate Path† systems, and its ClearPAC* MS gravel packing fluid system, to ensure a complete pack around the sand control screens.

OptiPac Alternate Path systems use shunt-tube technology to fill the voids that can form during gravel packing even under fracturing conditions. The shunts are installed along the screens, each with a series of evenly placed nozzles.

"When a bridge forms, the slurry naturally diverts into the shunts," Al-Harthy says. "When slurry encounters a nozzle facing a void in the open hole, it flows out to fill the unpacked annulus, and the process continues until the interval is fully packed."




Horizontal open hole completion with OptiPac



OptiPac screens and cutaway section of a nozzle

OptiPac systems are part of an integrated approach that ensures that screens are fully protected in high flow-rate wells, and is utilized in-conjunction with SandCADE*, gravel-pack design and evaluation software to help engineers design, execute and evaluate the entire job.

ClearPAC MS, which is an advanced viscoelastic surfactant, was selected as the carrier fluid on the first two Silvertip wells because of its excellent sand suspension capabilities, even at very low shear rates. The sand suspension and low friction pressure characteristics allow it to perform exceptionally well in the long intervals of both open hole and cased hole completions. The ClearPAC MS fluid also incorporates a breaker system (based on MudSOLV technology) to help dissolve filter cake that remains in the wellbore after the gravel pack is completed. By combining the breaker system with the carrier fluid this allowed Shell to eliminate the need to reenter the well, saving valuable rig time.

"To compensate for the narrow operating pressure, we also modified the mixing equipment on our stimulation vessel," Al-Harthy says.

Schlumberger DeepSTIM II stimulation vessel

This equipment, called the POD* programmable optimum density blender, mixes the fluid and the gravel before it enters the pump. The POD normally operates at rates of above six barrels a minute, but for the Perdido wells the equipment was modified to accept half the rate of fluid and proppant, to maintain pumping pressures within the narrow margins.

"We conducted a number of trials and extensive modeling beforehand to make sure that the equipment, fluid and overall design would perform as planned," says Al-Harthy.

ClearPAC MS Fluids are used in OptiPac operations to ensure proper gravel transportation and controlled leakoff through the nozzles of packing shunts.


MudSOLV: Filter Cake Breaker
Part A shows nonaggressive, slow-acting, MudSOLV solutions remove the filtercake more uniformly, resulting in higher retained permeability across the entire interval.

Part B shows aggressive treatments like acid create localized open areas (wormholes or pinholes) in the filtercake, leaving large areas of filtercake unremoved, generally over areas having lower permeability.

## Monitoring in real time

Throughout the process, Shell and Schlumberger engineers in distant locations were able to collaborate efficiently in real time using the InterACT* connectivity, collaboration, and information system. InterACT's robust design allows it to continue working, even in areas with marginal communication links.

## Working the plan

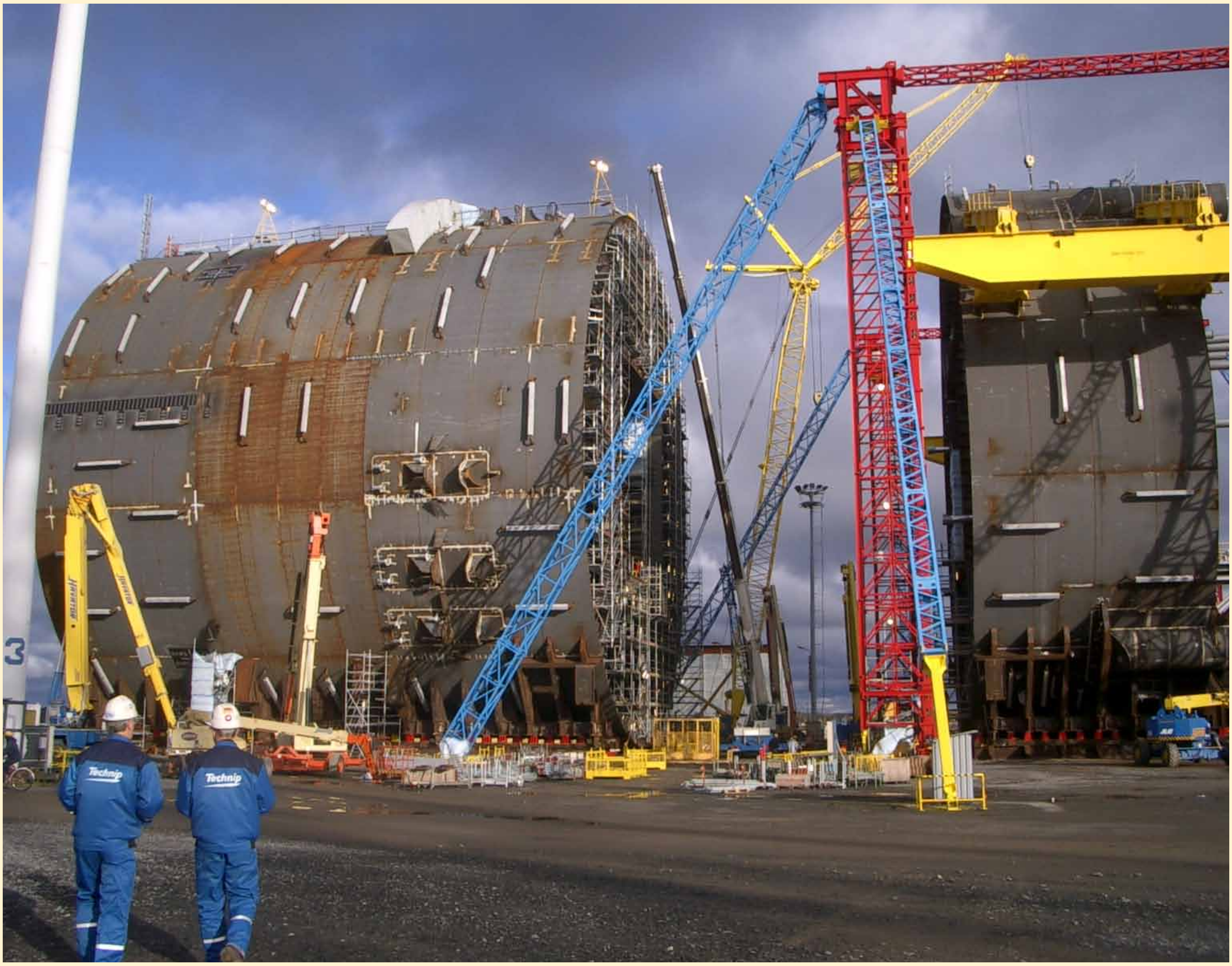
"We really did our homework," Al-Harthy adds. "Using powerful models and simulations, we worked together in a highly collaborative environment with Shell, to evaluate all the risks and to ensure successful execution. Perdido is a frontier development, so there were many uncertainties, but at the end of the day the modeling was correct and these jobs were performed as designed. The work we did on those first two wells will guide many of Perdido's future well completions."

*Mark of Schlumberger
†Mark of ExxonMobil Corp.; technology licensed exclusively to Schlumberger

Schlumberger

**Schlumberger**
1325 S. Dairy Ashford
Houston, TX 77077
U.S.A.
Tel: +1 281 285 1300
Website: www.slb.com/sandcontrol

# TECHNOLOGY AND TEAMWORK ACHIEVE WORLD CLASS SUCCESS FOR SHELL PERDIDO




Perdido Spar at Technip's fabrication yard in Pori, Finland.

In the high-risk ultra deepwater environment, success depends on two key components: technology and teamwork. Shell and Technip have applied innovative technologies and worked in concert as a team to achieve project success and set several world records for the Perdido Regional Host.

## Resources for Results

Shell selected Technip to provide Engineering, Procurement and Construction (EPC) of the Perdido Spar hull and mooring system.

Shell's choice of Technip as its EPC company is a natural outcome of their long-term working relationship and Technip's extensive experience in Spar development. In fact, the Perdido Regional Host is the fourteenth Spar delivered by Technip. In 2004, Shell and Technip had accomplished the world's first installation of steel catenary risers at 1,939 m (6,360 ft) for the Na Kika project.

Technip was able deliver the special aspects of the Perdido project because of its engineering design expertise, industrial assets (manufacturing plants, spoolbases, construction yard) on five continents, and its own fleet of specialized vessels for pipeline installation and subsea construction.

## Spar at Record Ultra Deepwater Depth

Moored in close to 8,000 ft of water, the Perdido Spar is the deepest Spar production facility in the world and the first with DVA (direct vertical access), which will reduce drilling costs, simplify workovers, and facilitate access to subsea equipment. The Spar has a robust design that will help the facility weather extreme hurricanes better than other traditional production platforms.

Technip's responsibilities encompassed Spar hull and mooring system design and fabrication, loading out onto a transportation vessel, transportation, and quayside delivery at a yard of the Gulf of Mexico. Technip's operations and engineering center in Houston performed the overall project management and the global engineering design. The detailed hull design and fabrication was carried out by Technip's yard in Pori, Finland. It should be noted that the Perdido project delivered the best safety performance to-date, for a Spar delivered from Pori, with no LTT's in over 2.5 millions manhours worked.

## Extended Length Flowline and Pipeline

Technip has helped set two new industry records associated with the flowlines and risers. Perdido is the deepest reeled flowline installation at a water depth of 2,961 m (9,713 ft). The facility also features the deepest reeled steel catenary riser installation at a water depth of 2,469 m (8,100 ft). The flowline and riser have a total length of 13.2 km (8.2 miles). The pipeline reached a maximum water depth of 9,713 ft along the route.

Technip used its high-technology Deep Blue vessel to lay pipelines and risers for the Shell Perdido project

Technip's operating center in Houston executed the project. The pipeline was welded at the Group's spoolbase in Mobile, Alabama. The offshore installation was performed using the Deep Blue, Technip's deepwater pipelay vessel.

## Umbilicals

Technip provided the engineering and manufacture of a total of four dynamic umbilicals, three static umbilicals, and two steel tube flying leads with associated topside and subsea hardware. Technip set another industry record for the umbilicals: the Perdido 1TOB umbilical is the deepest umbilical at 2,946 m (9,666 ft). The total umbilical length was approximately 51,729 m (169,723 ft). Prior to manufacture of the main umbilicals for the project, Technip's DUCO division had built a prototype umbilical that was subjected to a series of qualification tests to prove the design for the challenging ultra deepwater environment.

Duco 1TOB 3 pass umbilical

Perdido Spar as it is being transported to the final outfitting yard in the Gulf of Mexico.

## Technology Driving Opportunity

Shell Perdido's success is a testament to the leadership of both Shell and Technip in turning high risk challenges into safe and high-reward opportunities in the ultra deepwater subsea market. The Shell Perdido project is a great milestone for Technip towards achieving its goal to become a reference company for HS&E, on-time delivery and new technology.

Technip

**Technip USA, Inc.**
11700 Katy Freeway - Suite 150
Houston, Texas 77079
Tel: (281) 870-1111
Website: www.technip.com