1300 FATHOMS

A new oil platform in the Gulf of Mexico is producing from wells at depths unthinkable a generation ago.

By John K. Borchardt

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ROYAL DUTCH SHELL

▶ The final construction of the *Perdido* spar was completed in Ingleside, Texas.

▲ The *Perdido* production platform sits in about 8,000 feet of water 60 miles beyond any other development in the Gulf of Mexico.

There's a lot of oil lying under the sea that can feed the needs of the modern world, but developers will have to go into ever-deeper waters to retrieve it. And reaching it requires more than just using a longer pipe.

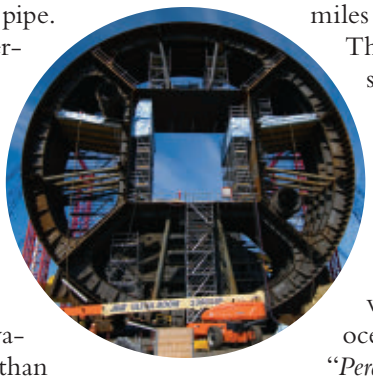
The International Energy Agency estimated in 2005 that deepwater and ultra-deepwater rock formations contain as many as 300 billion barrels of recoverable oil, more than Saudi Arabia's proved reserves. Deepwater is any depth greater than 1,000 feet, and ultra-deepwater exceeds 4,500 feet. World demand for energy makes it profitable to go to those depths.

Shell developed the Gulf of Mexico's first deepwater project, *Cognac*, more than twenty years ago and has been steadily developing new fields at greater ocean depths. Others active in the deepwater business are BP, Exxon Mobil, Chevron, and Petrobras. ConocoPhillips, Elf Aquitaine, ENI, and Statoil are all developing deepwater projects.

It requires a combination of very large financial resources and a sound command of specialized technology, much of it newly developed, to drill and produce oil fields at great ocean depths. Plenty can go wrong, as BP's Macondo well blowout has demonstrated.

The depths place engineering demands on equipment not seen on land or in shallower waters.

Shell Oil has produced its first oil and natural gas from the world's deepest offshore drilling and production facility, the *Perdido* development, in the Gulf of Mexico about 250 miles south of Houston.



The production platform sits 60 miles beyond any other development in the Gulf. The *Perdido* platform sits in approximately 8,000 feet of water, and will access reservoirs deep beneath the ocean floor.

"*Perdido* opens up a whole new frontier in deepwater oil production," said Tyler Priest, oil historian and professor at the University of Houston. "It is the most technologically advanced facility in the world." The record-setting ocean depth is one frontier. Another is the rock formation known as the Lower Tertiary. *Perdido* is the first production facility to tap this geologically complex oil reservoir.

Perdido is designed to produce hydrocarbons from not one, but three, oil fields. The platform floats over the largest of the three fields, Great White, which is penetrated by 22 wells. Another 13 wells penetrate the more distant Silvertip and Tobago fields. The Tobago field is the deepest of the three, at an ocean depth of more than 9,500 feet.

▼ The *Perdido* spar was taken by barge for installation at its final location, where it was mated with the topsides.

▲ A portable construction crane prepares to position the *Perdido* spar, which is held upright by ballast and cables.

▶ The *Perdido* platform has its own drilling rig, which drilled some wells and is used for periodic maintenance.

Some of the wellheads are as far as seven miles from the *Perdido* platform. The wells themselves extend about 14,000 feet below the ocean floor. They are tied into a subsea production network directly below the spar.

Together, the three fields contain 650 million barrels of oil equivalent (crude oil plus natural gas and natural gas liquids) of which 300 million boe is thought to be recoverable, according to Marvin Odum, president of Shell Oil Co. Daily peak production is forecast to be 130,000 boe.

"*Perdido* presented technical challenges unlike any we've ever seen in the Gulf of Mexico," Odum said. Challenges included the complex, highly faulted hydrocarbon rock reservoir, the extreme ocean depth, and record water pressures. The pressures place strict demands on the subsea equipment used to develop and produce oil. Much of the pioneering technology hadn't been developed when Shell and its partners (Chevron, BP, and Nexen) successfully bid on oil leases that constitute the project more than ten years ago. Shell is the operator of the project.

Generally speaking, the greater the water depth, the more expensive the platform needed to produce the oil field. Deepwater production rigs have been used in the Gulf of Mexico since 1969 when Shell's *Cognac* platform began producing oil and gas from wells drilled at an ocean depth of 1,025 feet. This manned platform continues to produce hydrocarbons, and its legs sit on the ocean floor.

As companies began to produce oil and gas from under ever deeper waters, platform designs evolved to reduce costs. Oil companies are now installing production platforms designed to float in the waters above the wells using different types of mooring lines that anchor them to the ocean floor. For example, Shell's *Perdido* platform floats in approximately 8,000 feet of water—roughly equivalent to six Empire State Buildings stacked one atop the other. Some of the remote wells produced by *Perdido* are in ocean depths approaching 9,500 feet.

Costing $3 billion, the *Perdido* platform has also been called a production hub because it is being used to produce hydrocarbons from the three different fields. The design is called a spar and is less expensive than other types of offshore platforms. It consists of production facilities called topsides that sit above the ocean surface and a spar built from multiple vertical sections that sits below the ocean surface. The two units are connected by a midsection containing ballast.

The structure is moored to the ocean floor. The spar contains a heavy counterweight at its bottom so the platform does not depend entirely on its mooring lines to hold it upright.

Technip built the spar unit in Pori, Finland. It was transported by barge to Ingleside, Texas, where it was equipped for offshore installation before being barged to its destination. Kiewit constructed the topsides in Ingleside. The two units were mated together at sea.

The large number of wells, 35, were needed to efficiently develop the three oil fields associated with the *Perdido* development. That's because the fields contained many geologic faults and had to be compartmentalized, according to project manager Dale Snyder.

The cost of bringing in mobile offshore drilling rigs designed for deepwater would have been huge, Snyder said. Instead, the *Perdido* platform contains its own drilling unit. Because of the horizontal distance of some of the wells, they were drilled by a drilling rig leased from Noble Corp., the *Noble Clyde Boudreaux*. The drilling rig on *Perdido* was used to drill some of the wells and is already being used for periodic well maintenance operations performed on existing wells. The drilling rig on *Perdido* may be used years from now to drill additional

wells for enhanced oil recovery operations as production rates decline with depletion of the oil reservoir.

The wells contain long horizontal segments that radiate out from the wellhead. This arrangement penetrates a large fraction of the reservoir volume to increase the efficiency of extracting oil and gas.

SUBSEA EQUIPMENT

One problem at the ultra depths is the formation of gas hydrates. (Gas hydrates caused the failure of the first attempt to use a containment dome to collect oil from BP's Macondo oil well blowout.) To prevent gas hydrate formation at *Perdido*, the produced liquids and gas are separated in caissons that are part of the sea floor pressure-boosting system. This is a first for the Gulf of Mexico. Normally this separation is done on a production platform.

Development of the necessary subsea separation equipment development required a multi-year program carried out at the same time as the production platform construction and other phases of the project. Liquid separation testing was performed using full-scale operating components to eliminate possible scaling up effects. Using full-scale components also provided valuable information on how to operate the system. The result is a 350-foot-long caisson embedded in the sea floor and topped with an inlet assembly.

As well fluids enter the inlet assembly, cyclone action separates the liquids and gas. The gas flows up the riser pipe to the surface for additional processing. The liquids drop into the caisson.

An electrical submersible pump at the bottom of the caisson controls liquid levels. The full-scale testing mentioned earlier allowed engineers to determine how to best control foaming and adjust the pump to control liquid levels in the caisson.

Relatively low reservoir pressures in the *Perdido* wells require pumping for production. It is provided by 1,500-hp pumps, and most of the details about them are proprietary.

Think of this part of the process as sucking the oil out of the rock through a straw. Subsea lift is adding hundreds of millions of recoverable barrels of oil to *Perdido* and Shell's other deepwater oil fields. The technology also enables recovery of high viscosity "heavy oil" from deepwater fields offshore Brazil, including Shell's BC-10 project now beginning production.

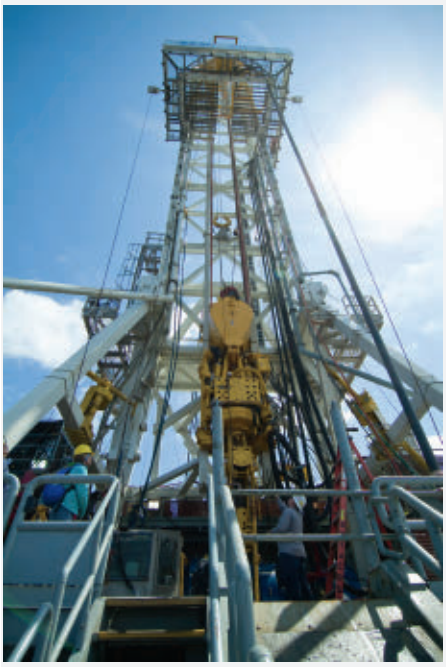
To develop subsea pumps for *Perdido* required going beyond the pump designs available more than a decade ago when design work for the *Perdido* project began. Pressure booster capabilities of older pumps had to be doubled and increased power levels were required.

Finally, the powerful subsea pumps are used to send the oil and natural gas up to the platform, a mile and a half above, for further processing, before the hydrocarbons are finally sent to shore through pipelines.

Advanced Safety Features

Since about 150 people work on the *Perdido* platform at any one time, safety is a primary concern. The *Deepwater Horizon* tragedy illustrates the cost of a failure in terms of lost lives, environmental damage, and cleanup. With its large-scale use of newly developed equipment and technology for the production of oil and gas, safety precautions at *Perdido* incorporate advanced technology as well. Among the advanced safety features on the *Perdido* platform are blast-resistant crew living quarters, and a blast-rated firewall spanning the production and cellar decks. There is also a high-capacity automatic dual foam and deluge active fire suppression system. A rapid blowdown system enables personnel to depressurize all equipment in case of a fire.

Because *Perdido* is a new facility, all equipment including the blowout preventer is new, with a known history. (This wasn't the case for the *Deepwater Horizon* drilling rig whose blowout preventer was ten years old and been subjected to a number of modifications.) Unlike the Macondo well, where high reservoir pressures created a massive blowout, *Perdido* is producing from a low-pressure hydrocarbon reservoir. This reduces the possibility of a blowout.



There are two high-capacity, long-range Sikorsky S92 helicopters dedicated to standing by to permit rapid crew evacuation in the event of an emergency. The helipad is large enough to accommodate both helicopters at once. In addition, there is a 27-person fast rescue boat.

Hurricane season always poses a threat to offshore drilling and production platforms. The *Perdido* platform is designed to stay upright even if torn loose from its massive moorings. Like an iceberg, only 10 percent of the structure is above the waterline. This helps *Perdido* maintain a vertical position. Moreover, it is designed to tolerate a tilt of 14 degrees. It moves up and down only a few meters with the ocean swell during storms.

The project has accumulated more than 10.5 million work hours without a lost-time injury. ■

Pipes called risers carry the produced oil and gas to the surface for storage. Snyder said that a separate riser for each well is unrealistic because each would weigh more than one million pounds at these water depths. Since the fluids from different wells are being combined at the seafloor, only five production risers are needed for the project's 35 wells.

Further processing is performed on the platform. The crude oil is then treated with additives designed to improve flow properties. Chemicals are added to the natural gas to prevent formation of gas hydrate ice crystals that can plug undersea pipelines.

Two new subsea pipelines, a 79-mile oil line and a 105-mile gas line, connect the production platform to the pipelines that will transport production to shore.

The many advances in the design of the *Perdido* subsea equipment prompted ASME's International Petroleum Technology Institute to award its 2010 Geoca Mechanical Engineering Achievement Award to G.T. Ju, manager of subsea hardware and umbilicals at Shell International Exploration and Production Inc. Established in 1965, the award recognizes distinguished and meritorious achievement for service in the field of petroleum mechanical engineering. Ju developed many of the key subsea technologies being used for the first time in the *Perdido* project.

Technology developed for *Perdido* will soon find additional uses in the Gulf of Mexico. Shell announced a new deepwater oil production and processing platform, to be called *Mars B* to be installed near its existing *Mars* deepwater platform.

Ocean depth is approximately 3,000 feet. The new tension leg platform will be able to produce and process 100,000 barrels per day of crude oil and natural gas from the Olympus deepwater discovery. It will also provide crude oil processing for two other recently discovered deepwater fields, West Boreas and Deimos.

Shell will operate the project and currently holds a 71.5 percent working interest. BP holds the remaining 28.5 percent. First production is expected in 2015.

LOOKING TO THE FUTURE

Perdido is a test laboratory for newly developed equipment and technology never used before. However, unlike a real laboratory, failed experiments cannot be tolerated. *Perdido* offers a model for other Shell and other oil companies to follow in coming years as they develop more fields in this emerging deepwater area known as the Lower Tertiary trend. More than a dozen big oil fields have been discovered in Lower Tertiary rock formations existing in a 300-mile band on the outer edge of the U.S. Gulf along Texas and Louisiana. Like *Perdido*, they are in very deep water.

Shell is already considering building four new production platforms to produce new fields it has developed in the deepwater Gulf of Mexico. Like *Perdido*, these platforms would tie together production from different fields not large enough alone to pay for their own expensive production platforms. Meanwhile, the three *Perdido* fields have a projected productive life of 20 years. This may increase with the development of improved production technology. ■

The Smart Oil Field

Smart oil fields are designed with instrumentation allowing use of real-time information in producing, processing, and transporting hydrocarbons. Fiber optics, powerful computers, and skilled personnel have made it possible to monitor drilling, well completion, production, and well stimulation operations at all stages of a field's life. The objective is to increase hydrocarbon recovery efficiency from the rock while improving safety and cost effectiveness of field operations.

Improved seismic imaging technologies and improved drilling rig capabilities have made it possible to drill within accuracies of one or two meters. This enables horizontal wells to be drilled close to the top of the oil reservoir where the hydrocarbons are and away from underlying brines that often exist in hydrocarbon-bearing rock formations.

Sensors can now survive the high temperatures and pressures found in oil wells. They let field engineers quickly detect when water is entering the well. The oil company then can shut off production from that well. Reducing water production reduces oil-water separation costs and decreases the environmental impact caused by disposal of produced water.

Seismic data can also be collected continuously during production operations. Infrared and gamma ray tools and sensors can continuously gather additional data. These data enable the monitoring of reservoir properties such as permeability, porosity, and movement of formation fluids.

The technology also makes it possible to prepare and monitor three-dimensional oilfield maps in real time. Oil and gas flow rate into each well and cumulative production of each can be monitored in real time as well. This allows oilfield operators to adjust production rates of the different wells and determine where to drill additional wells to most efficiently and economically produce hydrocarbons.

Automated data management enables engineers to have more time to focus on non-routine events and to find ways to increase operations efficiency. The *Perdido* complex of three oil fields is the first smart field development in the Western Hemisphere and the first in deep ocean water.

Smart fields are the wave of the future. Speaking at an industry conference, Robert Perrons, learning manager at Shell, said, "At Shell, all new oil fields will be born smart." ■