CASCADE AND CHINOOK
DEVELOPING THE LOWER TERTIARY WITH THE FIRST FPSO IN THE U.S. GULF OF MEXICO
<table>
<thead>
<tr>
<th>Page</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>A BOLD DEVELOPMENT STRATEGY</td>
</tr>
<tr>
<td>10</td>
<td>RESERVOIRS AND WELLS</td>
</tr>
<tr>
<td>16</td>
<td>THE SUBSEA SYSTEM</td>
</tr>
<tr>
<td>28</td>
<td>THE FIRST FPSO IN THE U.S. GULF OF MEXICO</td>
</tr>
<tr>
<td>38</td>
<td>THE OIL EXPORT SYSTEM</td>
</tr>
<tr>
<td>46</td>
<td>OPERATIONS</td>
</tr>
<tr>
<td>54</td>
<td>COMPANY PROFILES</td>
</tr>
</tbody>
</table>
“The BW Pioneer is the first FPSO in the American sector of the Gulf of Mexico. It will also be the first platform in the Gulf to send oil to the coastline by shuttle tanker rather than by pipeline. This system introduces a new regulatory framework and licensing environment specifically developed for the Cascade and Chinook Project. All these achievements consolidate the expertise of Petrobras as an energy company acknowledged the world over for technological excellence.”

**Jorge Zelada**
Chief International Officer, Petrobras

“Petrobras has faced several challenges in the development of the Cascade and Chinook fields in the US Gulf of Mexico. Those challenges have been overcome with the expertise that has made this company a benchmark in ultra-deepwater technology for the energy industry around the world.”

**Orlando Azevedo**
President, Petrobras America

“Without a doubt, Cascade and Chinook is a pioneering project that brings a new concept in production to the U.S. Gulf of Mexico. The system is in full compliance with U.S. regulations, and in line with Petrobras’ safety, environmental and health guidelines.”

**Fernando Cunha**
Executive Manager for the Americas, Africa and Eurasia, Petrobras

“The Cascade and Chinook Project put together a great team of men and women, dedicated to improving ultra-deepwater exploration and production technologies to achieve the best possible results. It is a privilege to work with such a talented team.”

**Gustavo Amaral**
Upstream Senior Vice President, Petrobras America

“The deepwater drilling and operating experience that Petrobras America brings to the table makes it uniquely suited to develop the Cascade and Chinook fields. This is very much what we do for a living.”

**César Palagi**
Walker Ridge Asset Manager, Petrobras America
PETRÓLEO BRASILEIRO S.A. – PETROBRAS – is one of the largest energy companies in the world. With integrated operations in 28 countries, Petrobras produces the energy equivalent of more than two million barrels of oil per day. The company has been operating in the United States since 1987 and in Brazil since 1953.
The Cascade and Chinook ultra-deepwater fields are located in the Walker Ridge area of the U.S. Gulf of Mexico, about 15 miles apart and some 160 miles south of the Louisiana coast. The target zone – largely untested in waters this deep – is in a geologic layer known as the Lower Tertiary.

The Cascade discovery well, drilled in a water depth of 8,143 feet (2,481 meters) found oil in April, 2002. The discovery well for Chinook, drilled in 8,831 feet (2,962 meters) of water, reached total depth in June, 2003. The current and future production wells will all have subsea wellheads.

The resource is being developed by Petrobras and its partner, Total, under a three-phase plan approved by the U.S. Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE). Petrobras has held working interests in several Walker Ridge blocks since 1996, but when the 10-year leases were about to expire in 2006, Petrobras and its partners had a decision to make: whether to develop the resources or let the leases expire.

“Even though we found oil, it was not an easy decision to continue because of the location of the wells,” says César Palagi, Walker Ridge asset manager for Petrobras America. “They are in an area of the gulf with no infrastructure. The technical difficulties of the project were daunting.”

Three of the original partners, Devon Energy, Petrobras and Total wanted to continue. Amerada Hess and BHP Billiton, which had drilled the discovery wells, wanted out. Petrobras bought BHP’s share of the lease in August, 2006.

“Petrobras, Devon and Total decided to stay,” Palagi recalls. “Petrobras was chosen as the operator because
of its expertise in deepwater developments in the Campos Basin, offshore Brazil.”

Petrobras further increased its stake in the project by purchasing Devon’s share of the Cascade reservoir in January 2010. Petrobras now holds 100 percent of Cascade and 66.67 percent of Chinook. Total owns the remaining 33.3 percent of Chinook.

Orlando Ribeiro was the project coordinator for Cascade and Chinook in 2004. “When Petrobras bought BHP’s share and became the operator,” he recalls, “we proposed a phased approach that would give us the most flexibility in developing the fields.”

As it turned out, the innovative Petrobras plan included something new for the U.S. Gulf of Mexico.

**CASCADE AND CHINOOK** are located in the Walker Ridge area, about 160 miles south of the Louisiana coast.

**FLEXIBLE PLAN**

“We wanted to use subsea wells combined with a subsea boosting system, plus a floating production, storage and offloading vessel,” Ribeiro explains. “Although FPSOs are a proven technology, there were none deployed in the Gulf of Mexico. Given the remoteness of the resource, the extreme water depth and uncertainty of the reservoirs, the FPSO was a natural choice.”
It was also familiar technology for Petrobras, which employs more FPSOs and deepwater drilling rigs than any other operator in the world.

The main reason for selecting an FPSO system is safety. The FPSO serving Cascade and Chinook is moored to a turret buoy that provides full weathervaning capability, which allows loading tankers to approach from downwind and tie up to the FPSO bow to stern. The detachable turret buoy not only provides a mooring point, it allows the FPSO to disconnect and safely leave when hurricanes enter the area, a threat that all gulf operators must deal with during the hurricane season.

Using a proven technology also minimizes the risk, the cost of construction and the time it takes to deploy the assets. In case the original development proves to be uneconomic, the FPSO and shuttle tanker can even be redeployed to other fields.

“The phased approach is common to Petrobras developments,” Ribeiro says. “In the 1980s we used it to push the water depth limits from 1,200 feet to more than 3,000 feet. Now, with Cascade and Chinook, we have gone far beyond that as we continue to build on our experience.”

When the project began, there were no other fields producing from the Lower Tertiary in ultra-deep water. It was truly a frontier venture. For the project development team, the biggest challenge was managing the uncertainties.

The team settled on a plan that can accommodate as many as 16 wells, but began production with only two. All of the produced fluids will be processed aboard the FPSO, which can handle up to 80,000 barrels of oil and 16 million scf of natural gas per day.

The oil is offloaded onto shuttle tankers and the gas is exported through a pipeline that ties into the Discovery system, located northwest of Cascade and Chinook in about 3,000 feet of water.

The first two production wells, one from Cascade and one from Chinook, are completed and ready to produce. A second well into Cascade, originally scheduled for completion in 2010, was delayed by the moratorium on drilling after the Deepwater Horizon accident in the Gulf of Mexico.

“Once we start producing from Cascade and Chinook, we will be gathering the information that will guide us in developing the next phase,” Ribeiro says. “We will be learning more about the reservoirs every day.”
Cascade | Chinook

Shuttle Tanker

FPSO
SAFELY ADVANCING THE TECHNOLOGY

Throughout the planning phase, the project team extended the boundaries of deepwater technology. Above all, their goal was to do it right.

“We advanced the technology on several components and systems, not because we wanted to, but because there was no alternative,” Palagi says. “We did it in a very responsible way. We kept asking ourselves, is there anything that could stop the project if we go this route? The answer I got from the technical guys was always, ‘No’.”

Despite the need to bring Cascade and Chinook on stream quickly, safety was never compromised. The project completed more than 2 million hours of offshore work without a single lost-time incident.

TEAMWORK ON A TIGHT SCHEDULE

By petroleum industry standards, Cascade and Chinook are being developed on a fast track. The integrated project team grew from 12 people in 2006 to a peak of more than 140 people by 2008. Most of the Petrobras team members have at least 20 years of experience in the oil industry and more than 10 years of experience developing offshore fields in deep water.

“Projects like this are very much what we do for a living,” Palagi adds. “This is a project that attracts people and keeps them motivated.”

THE NUMBER ONE REASON FOR THE SUCCESS OF THE PROJECT IS THE EXPERTISE AND THE DEDICATION OF ITS PEOPLE.
What may turn out to be one of the most significant discoveries in the Gulf of Mexico was almost overlooked. The original exploration plan in 2002 was to drill a relatively shallow wildcat into what is now the Cascade field, but the main target, the Miocene sands, contained no oil. Then the partners decided to go deeper.

“We still had money in the budget for that well,” says Julio Syrio, reservoir manager for Cascade and Chinook. “The seismic data showed some interesting structures in a deeper formation, so our geoscientists agreed we should drill deeper than the original plan. Our partners agreed, and in April 2002, we reached a high pressure reservoir sand that could potentially hold a lot of oil, and that became the discovery well for Cascade.”

Chinook, discovered in the following year, was equally promising.

“The two fields are similar,” Syrio explains. “They have the same sands as the Wilcox formation, but they’re not strictly analogs. The main characteristics of these reservoirs are that they are very deep, and the pressures are very high compared to what we normally find at that depth.”

In a well with a true vertical depth (TVD) greater than 27,000 feet (8,230 meters), drillers typically encounter pressures between 11,000 and 12,000 psi. Cascade and Chinook each came in around 19,500 psi. There are many possible reasons for the excess pressure, but the truth may never be known, or at least not until the fields are fully developed and studied. One theory is that the reservoir and adjacent formations acted like a pressure cooker when the oil originally formed, and there was no way for the pressure to escape.

“Such high pressure reservoirs are not unheard of,” Syrio notes, “but normally, they are very small. What’s unusual here is that the reservoirs are much bigger than we expected, and it looks like they are somehow connected.”
**THE DEPOSITIONAL SYSTEM**

Until the mid-1970s, most petroleum geologists agreed that they were not likely to find offshore hydrocarbons below a certain depth. Anything beyond the Outer Continental Shelf, they reasoned, was just mud. What they didn’t count on was the powerful effect of sand and sediment that was carried far out to sea through channels on the seabed.

Some 60 million years ago, great rivers began pushing a steady stream of organic-rich sediment into what is now the Gulf of Mexico. Most of the sediment spread out, settling to the bottom in the familiar depositional systems that geologists understand well.

There is a point, however, where the seabed in the Gulf of Mexico changes quickly from a gentle slope to a steep gradient. When sediment that would ordinarily settle to the bottom reached the edge, it began sliding down the slope on its own, gathering energy and carving gullies and canyons on the way. As the small rivers of sediment again reached relatively flat areas, the sediment stacked up until the deposit was tall enough to divert the flow right or left.

“\[The reservoirs we’re dealing with today were deposited in this fashion over the course of five to ten million years,\]” says Elizabeth Watkins, reservoir geologist for the Cascade field.

“The sediment came in so fast that the weight caused it to sink,” adds Carlos Ferro, primary geologist for the Chinook field. “It’s a process we call compensational stacking. The amalgamated or ‘stacked’ sands in Cascade and Chinook are quite thick.”

**THE WORLD-CLASS WILCOX TREND**

The Cascade and Chinook reservoirs are at the eastern and deepest end of the Paleogene or Lower Tertiary zone, a geologic period that began about 65 million years ago following the great extinction of dinosaurs, and continued through the time when mammals evolved on earth. Within the Lower Tertiary, the Wilcox stratigraphic zone has been a prolific source of onshore oil in North America since the 1930s.

In 2001, a surprising wildcat discovery in the western Gulf of Mexico linked the depositional system of the onshore and relatively shallow-water offshore Wilcox trend to the Perdido Fold Belt in 7,790 feet (2,375 meters) of water. The subsequent discoveries of Cascade in 2002 and Chinook in 2003 pushed the known extent of the Wilcox trend at least 275 miles to the east.

“The Wilcox may be one of the last traditional types of plays, where we’re getting oil from sand as opposed to the unconventional plays where operators are extracting oil from shale,” Watkins says. “The challenging and exciting thing about this is the sheer amount of sand and sediment we’re dealing with. When you say the Wilcox, people think of just

---

**GENERALIZED CROSS-SECTION**

of geology for the Cascade and Chinook fields.
this one monolithic sand body, but the Wilcox includes many different layers of sand.”

Sometimes these sand layers are very similar, which makes an operator’s life easier, but more often there are differences in porosity and permeability that can ultimately affect production.

“As we continue developing the field,” Watkins says, “we’ll get a better handle on the variations within the sands.”

CONSTRUCTING THE WELLS

Petrobras became the operator for both Cascade and Chinook in 2006. The producing reservoir includes the Wilcox 1 and Wilcox 2 sands, which correspond to the Eocene and Paleocene epochs. The gross producing intervals are more than 1,000 feet thick. Cascade is located in 8,200 feet of water and Chinook, 15 miles to the south, is in 8,800 feet of water.
The ultra-deepwater environment was challenging from the start of operations, when a strong loop current (eddy event) affected drilling in Cascade. Eddy events are like underwater hurricanes with powerful currents in excess of 3 knots. The resulting vortex-induced vibration puts enormous stress on the drilling riser and system. To reduce the harmonic effect, spoiler-shaped fairings were added to the upper 800 feet of riser to help water flow smoothly around the pipe. The fairings, drill pipe protectors and detailed procedures allowed drillers to finish on time and ahead of a critical subsea installation.

The wells are some of the deepest and most complex in the world, and the completions were especially challenging. The Tubing Conveyed Perforating (TCP) run alone was a world record.

“The TCP assembly, which was approximately 1,000 feet long, included almost 500 feet of perforating charges,” says Jonathan Shipley, Drilling manager for Cascade and Chinook. “We perforated in one operation, performed a cleanout trip, then ran a 1,000-foot long single-trip multi-zone (STMZ) system that included four packers, stainless steel screen, and various sleeves and ports. This was run on an inner string with shifting tools to function the sleeves and set the four packers in one operation. It was very challenging.”

A zone of tar became another challenge and a potential drilling hazard.

“We encountered 60 to 80 feet of tar, with no sand, at a critical pressure ramp,” Shipley explains. “Pressure forces the tar into the wellbore like a hard paste, and that can create costly problems.”

Although the industry is learning how to handle such hazards, it often requires transitioning to a smaller diameter drilling liner, which reduces the amount of flow area for cement and may not achieve the overall design objective of the well.

“We wanted to deliver an 8.5-inch ID production casing at total depth with good primary cement isolation,” Shipley says, “and we achieved that in each well.”
“The name of the game for a project like this is to be prepared for everything,” says Flavio Moraes, the Cascade and Chinook Well Engineering manager. “You plan for the good and the bad. You have plans for mitigating all kinds of anticipated risks. Sometimes we use all the plans: A, B, C and D. You want to get lucky, but there’s too much at stake not to have backup plans.”

A detailed analysis of the in-situ rock stresses, along with numerous runs on a gridded, 3-dimensional fracture simulator, determined the overall number of intervals. The STMZ technology gave completion engineers great flexibility in designing the job and controlling the cost. An STMZ completion also has lower logistical and operational risks, since it requires fewer trips compared to traditional deepwater stack-frac systems.

“If your completion design calls for several fractures, then typically you have to repeat that sequence for each stage,” Moraes says. “We knew that would take too long. The STMZ completions we ran significantly reduced the cost of these wells.”

While single-trip multi-zone technology is commonly used in much shallower wells, it had never been tried at depths much greater than 12,000 feet. At Cascade and Chinook, the wells are twice as deep.

“The treating rate was also greater than anything that had been applied before with this STMZ system,” Moraes says. “That was one of the contributions that this project has made, to demonstrate to the industry that single-trip multi-zone frac-pack completions could be done at these depths.”

Over the life of the fields, the reservoir pressure is expected to drop from its initial value of 19,500 psi to a low of about 8,000 psi, which highlights one of the challenges of working in ultra-deep water: Engineers must design equipment that will not burst under high pressure or collapse if the internal pressure drops.

“It is very important to pay complete attention to what you are doing,” Moraes says. “These are very difficult operating environments, so the team cannot be distracted. We detailed the risks, probabilities and likely outcomes. The best thing is to never have any surprises.”

QUALITY RESERVOIRS
Although the quality of the oil varies across the reservoirs, the average API gravity for Cascade and Chinook is around 22 degrees. The gas/oil ratio, which ranges from 100 to 250 scf per barrel, is very low. Most of the production is oil. Production should last for 25 to 30 years. In that time, the Lower Tertiary is likely to become a strategic new source of oil for the United States. More than 12 billion barrels of oil in place were identified as early as 2005, and there have been significant discoveries since then.

“Petrobras and other companies have identified several important structures in the Lower Tertiary,” Moraes says. “That is important for the United States, but also for the rest of the world.”
“THIS IS ONE OF THE MOST COMPLEX AND SOPHISTICATED PROJECTS THAT PETROBRAS HAS EVER DEVELOPED.”

In 2012, Cascade and Chinook became the deepest offshore oil and gas development in the world. Its wellheads, manifolds, flowlines, umbilicals and pumps are deployed across more than 12 miles of furrowed seabed at average depths of 2,590 meters (8,500 feet). From the beginning the development team had three main goals: Make this project safe, make it productive, and keep the cost down.

Safety and productivity are functions of corporate culture and engineering, while economics is a function of design and operational integrity. The subsea system for Cascade and Chinook demonstrates all three.

“Flexibility is the key,” says Sergio Porciuncula, Subsea manager. “Much of it comes from the use of standard modular equipment that can easily be expanded to accommodate future plans. The concepts we employed in Phase One contain many elements of the projected full-field development, and we pushed the envelope of subsea technology to develop some critical components.”

The subsea installation campaigns began in the second quarter of 2009 and ended in the second quarter of 2010.

“We knew early on that the success of these campaigns was key to the overall success of our project,” Porciuncula explains. “We used a variety of project management tools to coordinate simultaneous operations between the various vessels in the fields. Considering the entire project, we lost less than one day due to conflicts in our simultaneous operations.”
THE SUBSEA ENVIRONMENT
Beyond the Sigsbee Escarpment, which marks the edge of the Outer Continental Shelf, extensive regions of the seabed are furrowed. Like winds moving sand dunes in the desert, furrows on the seabed are a sign of strong currents. That combination of bottom currents and the furrows they formed in the soft clay were major factors in designing the subsea layout.

“One of these furrowed regions lies between the Chinook drill center and the FPSO,” Porciuncula says. “We found almost nine miles of furrows, with the widest being 174 feet from peak to peak, and up to 30 feet deep. Our studies showed that wherever the pipes spanned the wider furrows, seabed currents would cause the pipe to vibrate. The solution was to add strakes to disrupt the flow of water around them.”

FLOWLINES, CONTROLS AND UMBILICALS
The production flowlines on Cascade and Chinook are looped to allow round-trip pigging and the displacement of fluids from the FPSO. Cascade’s 9.6-inch diameter flowlines are insulated with more than three inches of thick polypropylene applied in multiple layers.

“Chinook’s flowlines are similar,” Porciuncula says, “but they’re fabricated for extra strength to span the furrows they encounter on the sea floor.”

The technology is called “pipe-in-pipe.” In this case, the flowline is protected by an outer pipe that is 14 inches in diameter and .75 inches thick. The cavity between the inner and outer pipe is filled with an aerogel nanoporous material that provides superior insulation.

The subsea control system includes five subsystems:
• The electrical power unit and master control station, both located on the FPSO
• The hydraulic power unit, also located on the FPSO
• The umbilicals, umbilical termination assemblies and the flying leads
• The subsea control modules
• The subsea and downhole instruments

SOME 23 MILES of flowlines were fitted with strakes to prevent current-induced vibration.
During normal production, operators control the subsea system from the FPSO’s master control station, which is integrated with the process controls so that the two systems can exchange alarms and sensor signals. The master control station interfaces with the subsea equipment via hydraulic, electrical and fiber-optic umbilicals to actuate valves and chokes, and to retrieve process control data.

“The umbilical also provides chemical injection services to each well,” Porciuncula says. “There is an umbilical termination assembly on the seabed and from there, control command signals are sent to the trees, pumping stations and manifolds through the infield umbilical and flying leads.”

Power umbilicals connect the FPSO turret to the power/pump interface for each drill center. Three triads – one of them is a spare – are used in each of the power umbilicals.

The umbilicals from both fields terminate at the surface in the FPSO’s detachable mooring buoy. If a hurricane threatens, the buoy itself can be uncoupled from the FPSO and submerged to about 150 feet below the surface for the duration of the storm.

“The installation was unique,” Porciuncula says. “We put in the buoy and mooring lines first, and later pulled the top ends of the umbilicals up using a winch installed on top of the submerged buoy. It was the first operation of its kind in the world.”
THE CASCADE AND CHINOOK DEVELOPMENT is powered by 260 kilometers of umbilical cable.
The initial subsea production equipment for Cascade and Chinook includes two 15,000 psi horizontal trees mounted directly on the marine drilling wellheads. The typical shut-in pressure at the trees is about 12,400 psi.

“The trees, connectors and structures are designed to withstand all life-cycle loads, including the riser loads during drilling, completion and workover operations,” Porciuncula says. “In areas of the seabed where we expect erosion, bends in the pipe will allow plenty of room for movement.”

Each of the trees is equipped with chemical metering valves to accurately dose chemical injections, and multiphase flow meters are mounted on the tree jumpers where the trees connect to the manifolds.

Each drill center includes one four-slot subsea manifold with two headers. The manifolds are gathering points for the production wells, with up to four wells clustered in the vicinity. Since the four-slot manifolds are lighter than six- or eight- slot manifolds, it was easier to find lift vessels that could handle them. If additional slots are needed in the future, it will be relatively simple to piggyback another four-slot manifold onto each of the existing ones.

Each manifold has two headers connected by a retrievable pig loop so that the pigging valve can be serviced easily. Individual wells may be directed into either header, which allows the wells to be segregated according to pressure and water cut.

The Cascade and Chinook production FSHRs have the highest pressure rating (10,000 psi) and are the deepest free-standing hybrid risers (8200 feet / 2,500 meters) in the world. The production jumpers are 9.6 inches in diameter with a wall thickness of 1.3 inches. The jumpers can handle up to 10,000 psi, and the gas export flexible line has a design pressure of 3,565 psi.
The combination of free-standing hybrid risers and an FPSO offers several advantages: it isolates the risers from the production platform, it significantly reduces the hang-off loads on the mooring buoy, and it meant that the risers could be pre-installed off of the project’s critical path.

“Free-standing hybrid risers also reduce the load on the vessel’s mooring system,” Porciuncula says, “and that improves our margin of safety.”

*NITROGEN-FILLED BUOYANCY CANS,* anchored to the seabed, were installed at the top of each riser to support the weight of the pipe.
EACH OF CASCADE AND CHINOOK’S free-standing hybrid risers is supported by its own buoyancy can. The system allowed the risers to be pre-installed.
THE BOOSTING SYSTEM
Petrobras installed its first electric submersible pump on a seabed well in 1994, and has since developed other fields using subsea boosting technology. The goal of subsea boosting is to enhance production by lowering fluid pressure at the wellhead. Even though the initial formation pressure at Cascade and Chinook is quite high, so is the weight of the fluid column above. Subsea boosting ensures that there will be enough differential pressure to keep the wells flowing for many years.

Booster pumps are typically installed downhole, but not on Cascade and Chinook. The reason is largely economic; retrieving a downhole pump from an ultra-deepwater well is prohibitively expensive. Instead, the project team designed an innovative submersible pump cartridge that rests horizontally on the seabed, which means that the cartridge can be installed and retrieved by cable.

“We placed one submersible pump in each field,” Porciuncula explains. “The pumps are rated at 20,000 barrels of oil per day, and they have bypass features that allow the wells to keep flowing even while a pump is being repaired or cleaned.”

Each of the subsea boosting pumps gets its electrical power through an umbilical cable attached to the variable frequency drive (VFD) located on the FPSO. The VFD, in turn, controls the speed of the pump. The electrical power is transferred through the turret of the FPSO using a slip-ring electrical swivel in the turret.

FLOW ASSURANCE
Deepwater developments typically use a combination of heat, insulation and chemical inhibitors to prevent icy plugs of gas and water from freezing in the subsea flowlines. The long tieback distances on Cascade and Chinook make that particularly challenging if production stops for more than 12 hours.

“Our flow assurance measures focus on the stabilization of wet flowlines and wet equipment following a shut-in and subsequent restart,” Porciuncula says.

“All of our trees, jumpers, manifolds, flowlines and risers are insulated to provide enough time for intervention before they cool to the point where hydrates form.”

That intervention window gives operators aboard the FPSO enough time to displace all of the produced fluids in the flowlines, risers, pump bases and manifolds with diesel. Methanol is injected to keep hydrates from forming in the wellbore, trees and well jumpers. Low-dosage hydrate inhibitors are also used to restart the system after a prolonged shutdown.

CONTRACTING STRATEGIES AND PROCUREMENT
Orlando Ribeiro, Project Coordination manager, recalls that the procurement phase had its own set of challenges. “Given the complexity of the development, we decided in 2006 to go with Engineering, Procurement and Construction (EPC) contracts for the major components, and lump-sum commercial contracts for our installations.”

The project was sanctioned in late 2007 and all of the major contracts were signed soon after. By the first half of 2008, 11 major contracts had been awarded for project goods and services. The three main challenges were ensuring that everything was fit for purpose, managing the interfaces between vendors and contractors, and making sure that components would be delivered on time.
“We also limited the number of potential providers,” Ribeiro says. “We stuck with world-class contractors and gave them the responsibility for product and process development. That freed our project team to concentrate on HSE, cost, schedules, interface controls and quality management.”

Major components were manufactured in 21 countries and Petrobras was on site to monitor the work. “You get what you inspect, not what you expect,” Ribeiro says, “that was our motto. It must have worked, because all of the equipment and installations were on time and within budget.”

“Some of the technology was completely new,” Porciuncula adds. “Electrical connectors for the boosting pumps, for example. There was nothing on the market that could handle the pressures we were dealing with at that water depth.”

Even the power umbilicals were a new design. By making them larger than anything else on the market – they are almost eight inches in diameter – the project team was able to deliver high-voltage electrical power some 12 miles across the seabed without using transformers.

A GOOD TEAM
When Porciuncula joined the project in 2007, the subsea team consisted of himself and four others. In two months he hired 50 people.

“Because this is an interesting project, I could get some of the best professionals in the United States,” he says. “A lot of people wanted to be part of this project, but even with good planning there are always surprises. If you don’t have a good team to overcome those surprises, you’re in trouble.”

The difference between success and failure is to work very hard and try to anticipate and mitigate all the risks.

“I am very proud of the subsea part of this project,” Porciuncula says. “In spite of all the complexity, we kept on budget and on schedule as it was planned in 2006. We matched our budget 97 percent. As a project manager, I think that is the best result I ever had.”
THE 97,000-TON BW PIONEER is 242 meters long and 42 meters wide. It can store 500,000 barrels of crude oil and is served by two shuttle tankers.
THE FIRST FPSO IN THE U.S. GULF OF MEXICO

“WHILE FLOATING PRODUCTION, STORAGE AND OFFLOADING SYSTEMS ARE COMMON IN OTHER PARTS OF THE WORLD, WE ARE PROUD TO BRING THE FIRST FPSO TO THE U.S. GULF OF MEXICO.”

When Petrobras began managing the Cascade and Chinook development project in late 2004, Antonio Corte and Orlando Ribeiro were in charge. They were, in fact, the whole team. One of their first discussions was how to best develop the fields.

“We explored several ideas and decided that an early production system (EPS) using a disconnectable Floating Production, Storage and Offloading (FPSO) vessel was the best approach,” says Corte, who is the EPS Project and Operations manager for the Walker Ridge asset. “We looked around the world to find other projects similar to ours, searching for vessels that were available for a short-term lease.”

At the same time, Corte and Ribeiro began building the team of drilling, reservoir, subsea, logistics and other specialists they would need to move forward. César Palagi became the Walker Ridge asset manager in 2005 and Ribeiro was named project coordinator.

“We spent all of 2006 on a feasibility study,” Corte says. “In 2007 we asked for bids and by October of that year, we awarded the contract to build the FPSO.”

ACQUIRING THE FPSO

Rather than building the FPSO from scratch, the project team decided it would be faster and more economical to refurbish an existing vessel, so that became part of the criteria. Bidders had to identify the ship they would use for the hull, and the contractors they’d hire to convert the vessel to an FPSO.

“We signed a contract with BW Offshore in October, 2007,” Corte says. “The ship that BW found was a double-hulled tanker working between U.S. and Caribbean ports.”
The conversion process began by sending the hull to China, where all of the deck steel was replaced and the decks reinforced to handle the weight of the production equipment that would be added later. The ballast and cargo tanks were not changed.

“We finished in China, and then in September, 2008 we moved the vessel to the Keppel Shipyard in Singapore,” Corte says. “We refurbished the original living quarters and added a second deck to accommodate additional crew, but the largest portion of the work was adding all of the oil and gas production modules and the turret system. As you can imagine, logistics was a big issue.”

Most of the topsides modules were built in Singapore. Some of the work to finish the vessel, however, was completed at sea during the two-month voyage from Singapore to the South Louisiana coast. After stopping for a crew change in Cape Town, South Africa and again to pick up equipment in Barbados, the FPSO arrived off South Louisiana on March 28, 2010.

The FPSO, now Bermuda-flagged and named the BW Pioneer, is 242 meters long and 42 meters wide. It can process up to 80,000 barrels of produced fluids and 16 million standard cubic feet of natural gas per day, and store 500,000 barrels of oil.

TURRET BUOY MOORING SYSTEM

One of the critical safety features of the early production system is the FPSO’s Turret Buoy Mooring System (TBMS), which allows the vessel to disconnect from the risers and leave the area in case of a storm.

During normal operations, the turret buoy is the point where produced fluids from the wells board the FPSO. It is moored in 8,200 feet of water by a system of wire, polyester and chain mooring lines attached to suction piles.

The system’s turret design allows the FPSO to weathervane around the buoy, so that the stern is always downwind. Since shuttle tankers offloading from the FPSO attach bow-to-stern, they also remain downwind.

The buoy itself includes two primary structures: the geostationary buoyancy cone and the turret, which can rotate. The buoyancy cone latches into the FPSO’s hull and contains upper and lower mating rings. The upper ring interfaces with the buoy’s latching mechanism, which supports the buoy and related loads while the buoy is connected.
“Constructing the buoy was a project in itself,” Corte says. “It’s huge, with a dry weight of more than 1,000 metric tons. Sealed tanks provide enough buoyancy to support all of the mooring lines and the riser system, while additional ballast chambers allow us to disconnect from the buoy and let it sink to a position that is safely below the waves in case of a major storm.”

The FPSO for Cascade and Chinook has a swivel stack located at the top of the turret that allows produced fluids to enter the onboard oil and gas processing equipment. While the rated pressure at the production manifold is 10,000 psi, production chokes located in the turret, reduce the pressure to about 1,000 psi before it enters the swivel. Additional functions in the swivel stack include the gas export, optical, and power and control.

Perhaps the most complex portion of the turret buoy system is the medium-voltage electrical swivel that delivers power to the submersible pumps on the seabed.
Throughout the summer of 2010, the FPSO anchored about 20 miles off the Louisiana coast. During that time, crews continued to prepare the vessel for first oil. They also repaired connections on the turret that had loosened during rough weather at sea. That delay, however, was just one of the challenges that typically arise on complex projects. Another was the winch for the turret buoy.

“The turret buoy was installed in August 2009, and then left submerged for nearly a year,” Corte explains. “We returned to the buoy at the end of August 2010, but when we tried to connect, we found a mechanical problem with the winch that pulls the buoy up into the ship. We had no choice but to release the buoy and fix the winch, which took about six weeks.”

The buoy remained below the surface, submerged at a depth of 56 meters, while the FPSO returned to the Louisiana coast. The ship returned to the site on October 12.

“That was the day we made history,” Corte says. “We were at a water depth of 8,200 feet (2,570 meters). When we raised the buoy and locked it in place, we had the deepest moored vessel in the world.”

With the turret buoy in place, it was time to connect the subsea components and the gas export pipeline to production equipment aboard the FPSO.

“Our Subsea group was able to expedite some activities before the FPSO arrived,” Corte says. “Normally we would have pulled the umbilicals to the buoy using a winch on the vessel, but instead, we installed a subsea winch and used it to pull the umbilicals to the buoy.”

Since the riser is too heavy to be supported by the turret buoy, the riser is suspended from a subsea buoyancy can and connected to the FPSO through flexible jumpers. Initially, the jumpers were simply moored to the turret buoy, but later the Subsea team used the TBMS winch to pull the jumpers to the buoy.

“Now that everything is connected to the FPSO, disconnecting takes about a day,” Corte says. “First we displace all of the oil from the subsea lines with diesel, and then undo several short connectors that attach the valves at the top of the buoy to the production flowlines on the FPSO. We also disconnect the electrical and control umbilical lines. After that, we open the TBMS latch connectors inside the turret and let it sink to a safe level below the surface. We’re then free to move the vessel out of the area. When we return, reconnecting takes only about 12 hours.”
THE TURRET BUOY is designed to disconnect from the FPSO and sink to a neutral depth of 56 meters, which is safely beneath the wave zone of large storms.
NEW OPTIONS IN THE U.S. GULF OF MEXICO

The Minerals Management Service (now the Bureau of Ocean Energy Management, Regulation and Enforcement) gave operators the green light to use FPSOs in the U.S. Gulf of Mexico in 2001. Five years later, Petrobras became the first operator to implement a project in the gulf using an FPSO.

Petrobras saw it as an opportunity to draw on its own experience and the industry’s best practices to help develop comprehensive regulations that would guide and ensure safe FPSO operations in the Gulf of Mexico for decades to come. The conceptual plan was approved by the MMS at the end of 2006 and was followed by a two-year period of close consultation with the MMS and U.S. Coast Guard.

One consideration was a law known as the Jones Act. This segment of the Merchant Marine Act of 1920 requires that all goods transported over water from one U.S. port to another must be carried in U.S.-flagged ships that are built in the United States. While the Jones Act did not apply to the FPSO, it did impact the choice of the shuttle tankers that serve the FPSO.

“An FPSO connected to the seabed in the Gulf of Mexico is considered a U.S. port,” explains Sergio Matos, Petrobras HSE and Regulatory manager. “It means that if you want to transport oil from an FPSO to another U.S. port, the Jones Act requires that the shuttle tanker must be U.S. built and flagged. That is the limitation.”

REGULATORY FRAMEWORK

Although the MMS had approved the concept of deploying an FPSO in the Gulf of Mexico, there were few regulatory guidelines. The rules that were in place dealt mainly with fixed and floating offshore platforms, but when the Cascade and Chinook development began, there was not a similar set of rules for FPSOs.

“We worked closely with the U.S. Coast Guard, the Minerals Management Service and later, with the Bureau of Ocean Energy Management,” Matos says. “The support of those agencies was key to navigating the overlapping jurisdictions in uncharted FPSO waters.”

The MMS focused mainly on the oil processing, oil production, and facilities safety aspects of FPSOs, while the Coast Guard made sure that the FPSO met all the marine safety requirements.

“Those interfaces are not easy, because you have systems that are common to both,” Matos says. “Power generation, for example, applies to both. That’s one point where maritime industry standards meet the standards of the offshore industry.”

The challenge was getting all the technical standards to work together, so that when something met an offshore production standard, it also met the requirements for marine service.

The Conceptual Plan was approved by MMS at the end of 2006 and the back-and-forth process of consultation with the MMS and USCG took about a year, from 2006 to 2007.

“After that, we spent extra time fine-tuning the regulatory requirements,” Matos adds. “This was the first project that tested the 2008 Memorandum of Agreement (MOA) between the two agencies for a ship-shaped hull. The MOA was written with the best of intentions, but when you put it to work, you find that particular systems fall under both the USCG and the MMS jurisdictions, sometimes with conflicting requirements. It was a big learning curve, and I hope the next operator who brings an FPSO into the gulf can ride on that curve.”
EQUIPMENT ABOARD the BW Pioneer can treat 16 million cubic feet of gas and process 80,000 barrels of fluid per day.
Deepwater projects around the world often face the same problem: Once you get hydrocarbons out of the reservoir, how do you get them to shore? The Cascade and Chinook development is far from the nearest oil pipeline, and building a new one just to service the project’s early production system would have been risky and expensive. Shuttle tankers were the safest, most reliable choice, so the contracts to build them were the first to be signed.

“Shuttle tankers, compared to pipelines, also have the advantage of being able to deliver to a variety of customers,” says Carlos Mastrangelo, Facilities manager for Cascade and Chinook. “In Brazil, they are the principal way to transport oil from the country’s vast offshore fields. We average two shuttle tanker operations per day in the Campos Basin.”

Duplicating the system in the Gulf of Mexico would have been relatively easy, except for a U.S. law known as the Jones Act. It requires that any tanker making deliveries from one U.S. port to another must be built in the United States, and owned and operated primarily by U.S. citizens. Beyond that, Petrobras had its own specifications. Finding just one ship that met all the requirements was nearly impossible. For this project, Petrobras needed two.

“Ours are the first purpose-built Jones Act shuttle tankers in the United States,” Mastrangelo says. “The challenge was that only a few U.S. shipyards could construct the vessels to our technical specifications and meet or surpass U.S. regulations, and it all had to be done within the project’s schedule.”
There is an important distinction between ordinary shuttle tankers and those that are built to serve an FPSO.

“Our experience in Brazil has shown that standard shuttle tankers have disadvantages in terms of maintenance, efficiency and risk,” Mastrangelo says. “Spills are not a problem, because you can stop operations quickly in case of an emergency. The problem with using a standard oil tanker for shuttle purposes is the increased maintenance and decreased efficiency because of the design of the vessel.”

A typical tanker has its loading and offloading manifolds on the side. Tankers that are built specifically to service FPSOs, as required by Petrobras, have duplicate manifolds on the bow. Having only side-mounted offloading manifolds makes approaching the FPSO and holding the position for up to 24 hours more difficult for ordinary tankers.

With a duplicate loading manifold on the bow, a shuttle tanker can tie up to the stern of the FPSO and remain in tandem throughout the loading operation. If there’s a shift in wind direction, both ships will weather-vane around the FPSO’s turret buoy mooring system. Connecting bow-to-stern also means that the offloading hose can be shorter, which reduces the risk of damage.

**A CREATIVE SOLUTION**

In 2006, the Cascade and Chinook development team needed two shuttle tankers, but it couldn’t buy or build them from scratch in time to meet the deadline. The solution was to change course. Instead of telling U.S. shipbuilders what they wanted, Petrobras asked the shipbuilders what they had or could produce.

“We called for a design competition,” says Dalmo Barros, Production and Midstream Operations manager. “Rather than giving American shipbuilders a list of our specifications, we provided only the minimum requirements and asked how they proposed to meet them.”

All of the American shipbuilders that were large enough to handle the job were asked to submit proposals. The requirements were prepared by a Petrobras committee that included members from every upstream and downstream department that would have a stake in Cascade and Chinook.

“We needed to see if we could work with something that was different,” Barros says. “What would happen, for example, if one of the bidding companies proposed a barge rather than a ship?”
The Petrobras team conducted studies before the bids went out. The challenge was to find a way to compare all the options and standardize them in terms of efficiency and safety. The team also worked with the U.S. Coast Guard to understand exactly what the Coast Guard expected from shipbuilders.

“When we sent the bid packages, we gave companies our functional specifications and our performance recommendations,” Barros says. “We never departed from Petrobras’ safety standards, but we also did not try to limit the bids to new-builds or conversions. We wanted the bidding companies to be creative. The solution had to meet the requirement for a ship to be built in the United States, and it needed to comply with all of our internal performance and safety standards.”

The contract for both vessels was awarded to the Overseas Shipping Group (OSG) in 2007. The company proposed converting one of the new vessels it already had contracted in a Philadelphia shipyard.

“That was something that we never could have expected,” Barros says. “The company took a new ship, sent it to another yard and converted it to be a dedicated purpose shuttle-tanker.”

The first of the two new shuttle tankers – the Overseas Cascade – was delivered in April 2010, some 30 months from the time the contract was signed. The second shuttle – The Overseas Chinook – was delivered in 2011.

“When we were waiting for the final commissioning of the Cascade and Chinook, we planned to put the first tanker to work in Brazil,” Barros says. “That changed after the Macondo well blowout in April, 2010. Instead of sending the tanker to Brazil, we kept the contract but allowed the ship’s owners to reassign the vessel to help with the spill.”

After the emergency in the gulf, the vessel was put to work in Brazil, performing operations similar to what it would be doing in the United States for Cascade and Chinook. That also gave the crew a chance to become more experienced with operating the ship.

When operations begin, the Overseas Cascade will make 7-day round trips to refineries along the Gulf Coast, serving an area from Corpus Christi, Texas, to Pascagoula, Mississippi.
“As we drill more wells, the second tanker will be put into service,” Barros says. “For now, we have enough storage capacity in the early production system to operate with one tanker.”

SAFE TRANSFERS

Petrobras has more experience with FPSOs and shuttle tankers than any other operator in the world. In 1980, the industry proposed the first purpose-built shuttle tanker, and it was deployed in the North Sea. The vessel included an innovation known as the North Sea Valve, which has become one of the industry standards for safe ship-to-ship transfers of oil.

There have been many improvements since then. One of the latest is an advanced safety system that links the offloading controls of the FPSO to the loading controls of the shuttle tanker, as Carlos Mastrangelo explains.

“The control systems talk to each other,” he says. “The vessels automatically exchange information, so that both systems act as one.”

Shipboard operators refer to the control systems as the “green line” protocol. The offloading system will not allow the FPSO to begin pumping oil to the shuttle tanker unless every pump, valve, connection and safety device signals that it’s ready.

“This system is standard across our fleet of FPSOs and shuttle tankers,” Mastrangelo says. “During a liquid transfer, if any component shows a problem, such as a valve beginning to close unexpectedly, it breaks the green line signal and stops the whole operation.”

Maneuverability and stability are also important for safe ship-to-ship liquid transfers. Thrusters on the shuttle tankers keep the vessel from drifting side to side. To help maintain the correct distance from the FPSO, both shuttle tankers are equipped with controllable-pitch propellers (CPPs), which allow the forward thrust to be reversed if needed, without reversing the ship’s engine.

“Imagine a ceiling fan in your house,” Mastrangelo says. “If you want to reverse the motor, the blades have to come to a complete stop first. It’s the same on most ships, but on our tankers, to reverse direction, the helmsman simply changes the pitch of the blades. It allows much faster and more precise corrections.”

For an extra measure of safety, a multi-service vessel, the Forte, remains with the FPSO at all times.

“The Forte is an important part of our operation,” Barros adds. “Even though the tankers have bow thrusters and a controlled-pitch propeller, we require a tug to assist the operation.”

THE GREEN LINE telemetry system monitors oil transfers from the FPSO to the shuttle tankers.
The heavy-duty tug has additional capabilities, including firefighting and spill response. When it’s not pushing tankers around, the tug helps maintain the offloading hose and performs other jobs around the FPSO, such as restraining the rotation of the ship during certain operations.

**OIL PIPELINE VS. SHUTTLE?**

In the planning stage of Cascade and Chinook, there was a fair amount of discussion about whether an oil pipeline or a shuttle tanker would be more economical. There were several factors, but the cost of a new oil pipeline, and the fact that it would have to tie into the Gulf of Mexico’s aging pipeline system, were primary considerations.

The question of a gas pipeline was less complicated. It was not so much a commercial decision, however, as it was a way to keep from having to flare some of the gas. A relatively small 6-inch gas pipeline was installed to tie into the Discovery pipeline system, which is 54 miles from the FPSO.

“In the beginning we could use all of the produced gas as fuel for the FPSO,” Barros says. “The ship can burn either diesel or natural gas. But as additional wells come on stream, there will be more gas than we can use offshore, so we need the gas pipeline.”

The decision to build a small pipeline for the gas and tankers to export the oil was more economical in the long run, and having the shuttle tankers added more flexibility to the project. Now other operators in Walker Ridge, including some in partnership with Petrobras, may use shuttle tankers as well.

**DELCIVERING SAFETY**

A portion of the bid package to build the tankers included a plan for training the people who would run them. Some of it, such as certification and minimum training on the equipment, is required. In addition, the training for Cascade and Chinook involved a mix of high-tech simulation and hands-on experience for the pilots and key personnel.

“While the shuttles were being built in the United States, we sent their crews to work on some of our tankers in the Campos Basin,” Barros says. “Later, when our first U.S. shuttle tanker was released from its duties in the gulf, we sent it to Brazil so the crew could work on their own ship.”

The irony is that when the project began, complying with the Jones Act as it applied to the shuttle tankers was considered to be the major challenge. Not so, according to Mastrangelo.

“The part of the project that we thought would be the most difficult, the first shuttle tanker, was delivered on the first day of the window, absolutely on time and with no change orders,” he says. “At the end of the day, the Jones Act, in fact, was not a bottleneck for this project.”
As new wells are drilled, the second shuttle tanker will be put into service. Eventually, shuttles will visit the FPSO every three to five days.
Petrobras has a long history of successful deepwater operations in Brazil’s Campos Basin, where it produces some 1.7 million barrels of oil and 26.8 million cubic meters of natural gas per day from 40 separate fields. That same proven technology and experience is now guiding the operation of Cascade and Chinook.

Operators in the Gulf of Mexico face many challenges: potential hurricanes, strong loop currents, and in the case of deepwater developments, a great distance from shore. To help manage these challenges at Cascade and Chinook, Petrobras deployed some of the industry’s most advanced data acquisition and simulation tools.

The technology includes the Production Surveillance Management System and the Digital Oil Fields Tool. There is also a system for monitoring data from the risers and mooring lines, and a dedicated electronic buoy that continuously tracks and records ocean data.

“We monitor all of these systems from both offshore and onshore,” says Luiz Guilherme dos Santos, Operations manager for Cascade and Chinook, and Phase Three project manager.

“To enhance the safety and operational integrity of our fields, we watch every phase of the operation from what we call our ‘Situation Room’ in Houston. From there, we not only see what is happening at the moment, we also run ‘what if’ scenarios that predict the effects of any changes in operating conditions. We also made dry-runs of all of the subsea operations before stepping onto the vessel, so we could avoid mistakes and operational problems later on.”
MANAGING PRODUCTION

The Production Surveillance Management System (PSMS) for Cascade and Chinook contains a set of tools that operators need to analyze production in real time. Historical data from the PSMS is also available for other applications within Petrobras, and it can be retrieved by authorized contractors over the Internet. Although the PSMS for Cascade and Chinook is designed for as many as 16 wells, the early production system required only three.

“The PSMS reports real-time well test information and approved well test results,” Santos says. “The PSMS uses the approved well test volumes and facility rate data to calculate a real-time facility battery factor. Any deviation from within a tolerance range tells the operations and engineering staff that certain wells may need to be re-tested, or that measurement points may need calibration or service.”

The last approved well test data is used in conjunction with the well flow times to calculate the estimated production from each well. Process meters and the gas export meters are also used to calculate the total oil and gas production from the facility. The PSMS provides detailed reports that include the latest well test results and test history for each producing well.

THE DIGITAL OIL FIELDS TOOL

A key component of the operations management system is the Digital Oil Fields Tool (DOFT), which serves as the primary source of information for safe and reliable production.

“The DOFT uses simulation results to understand the current state of the facility and predict future conditions,” Santos says. “The DOFT consists of four separate applications: Real-Time, Look-Ahead, Planning and the Operator Training Simulator.”

For added safety, two identical systems, including all four of these applications, are installed offshore aboard the FPSO, and onshore, in the Houston offices of Petrobras.

“The Real-Time (RT) simulator of the Digital Oil Fields Tool serves as a virtual plant of the modeled facility,” Santos says. “It simulates a wide range of information that is not typically measured, such as flow profiles inside the pipelines.”

The RT simulator indirectly receives its information from the FPSO and the subsea and boosting control systems via a database known as the Petrobras Historian. Measurements in the Historian continuously update the RT model’s boundary conditions, such as inlet and outlet pressures, and current states such as valve positions and setpoints. The RT simulator also provides the user with a wide range of inferred information, all based on a high-fidelity dynamic process model. The system can automatically tune the model, monitor hydrates and slugs, track pipeline pigs and detect leaks.

The DOFT system includes several distinct real-time, predictive, planning and training modes.

PREDICTIVE SIMULATOR

The predictive or “look-ahead” simulator accepts the initial conditions provided by the real-time simulator and uses them as a starting point for predicting how the system will react to change. Users can ask for the model to operate automatically at user-defined intervals – every hour, for example – or the changes can be input manually. In one hour, the system can predict what will happen as much as 36 hours into the future. At any point, the operator may stop the current look-ahead simulation and begin another.
PREPARING to deploy the metocean buoy, a device that will continuously monitor the weather and conditions of the sea.

Jaime Bernardini
E&P Logistics manager
THE “WHAT IF” SIMULATOR
The planning, or “what if” simulator, allows operators to study the predicted response of the Cascade and Chinook system to different operating scenarios.

“This planning mode runs independently from the real-time and look-ahead simulations, and it serves as a comprehensive flow assurance tool,” Santos says. “The planning mode can be run using preconfigured scenarios, such as shutting in or restarting a well, or changing the production chokes. We can also run simulations with changes that we introduce ourselves.”

Since the same process model is used for all modes of the Digital Oil Fields Tool, current process conditions from the real-time model can be used as the starting conditions for a planning session.

THE OPERATOR TRAINING SIMULATOR
The DOFT Operator Training Simulator (OTS) provides “hands on” training for the operators of Cascade and Chinook. The OTS operator interface mimics the real control systems. The screens and system responses that the operators see during training sessions are identical to what they will see in the field.

WEATHER WATCH
The Gulf of Mexico is notorious for its hurricanes, which typically form in the Atlantic Ocean between the beginning of June and the end of November. All operators in the gulf monitor the weather, and when storms threaten, they begin shutting in production and evacuating their manned facilities as much as a week ahead of time. The amount of time that a platform remains down depends on the type of facility, the amount of damage from the storm, and the time it takes for the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) and the U.S. Coast Guard to approve a restart. After a major storm, when many facilities are shut down, approvals can take several months even if the facility itself appears undamaged.

“The Cascade and Chinook development is unique,” Santos explains. “In our case, the turret system aboard the FPSO includes a moored buoy that allows us to disconnect the vessel from the wells in case of a hurricane. The buoy itself, which is connected to the risers through flexible jumpers, is then submerged safely below the surface until the storm passes. If we have to leave the area, the Digital Oil Fields Tool continues to monitor the field, so we know immediately after reconnection if we sustained any damage to the system.”

FROM THE CASCADE AND CHINOOK SITUATION ROOM at the Petrobras USA headquarters in Houston, managers can monitor the operations offshore in real time.
WEATHER AND OCEAN DATA

A separate monitoring system constantly gathers and stores information about the weather and conditions of the sea. Data such as wind speed and direction, wave heights, the speed and the temperature of the water and air are all fed directly into the supervisory systems on board the FPSO.

“That part of the data is gathered by our metocean buoy,” says Carlos Mastrangelo, Cascade and Chinook Facilities manager. “The current sensors, for example, can measure current speeds and directions from the surface down to a water depth of 1,000 meters. The information is transmitted hourly from the metocean buoy via two independent satellite links to two independent website bases. Petrobras personnel and the FPSO operators have uninterrupted access. All of the environmental data is also transmitted to Petrobras offices and integrated into the supervisory system.”
The monitoring system tracks not only short-term damage, but the long-term effects of normal use over the lifetime of the field.

“Our subsea monitoring system sends signals to the top of the buoys on the risers, and each buoy feeds its data to the central turret buoy, which stores all the information, even during a hurricane.” Santos says. “The only difference is that when we disconnect the buoy from the FPSO, the information is no longer being transmitted to Houston or the FPSO. When the FPSO returns and retrieves the buoy, all of the recorded information is fed into the larger control system.”

Using the stored data from the buoy, operators can quickly see how the subsea, riser and mooring systems behaved during the time the vessel was not there.

“Having that data available will minimize our downtime after a storm,” Santos says. “We’ll know as soon as we retrieve the buoy if there was any damage. After a major storm, it will be easier for us to show the BOEMRE and the U.S. Coast Guard that Cascade and Chinook is safe to resume production.”

**THE NEXT STEP**

Production from the Cascade and Chinook fields could continue 30 years, and that period may increase with advances in completion technology.

“Once we better understand the productivity of these wells and the reservoir, we will move forward with more drilling,” says Antonio Corte, EPS Project and Operations manager for Walker Ridge. “Phase Two of the Cascade and Chinook development is to fill the production capacity of the FPSO. Phase Three is not yet defined.”

The FPSO has a processing capacity of 80,000 barrels per day, which is well above the production from the first three wells. The advantage is that it gives the project team the time to study the reservoirs and determine how many more wells they will need. If additional wells prove the reservoirs to be as prolific as they seem to be now, Phase Three will be a shift from the early production system to a more substantial presence in the field.

“As we produce more of the reservoir, we will adjust our plan,” Santos adds. “For now, we must listen to the reservoir.”
WEB-BASED SYSTEM MANAGES SAFETY, ENVIRONMENTAL COMPLIANCE AT DEEPWATER CASCADE AND CHINOOK

Fully aware that meeting and validating all federal and state government regulations for drilling and production operations in U.S. waters was a daunting task, Petrobras made sure to acquire for its Cascade and Chinook deepwater development what it deemed to be the most complete compliance management system available.

Petrobras’ choice was the SMART system developed by Compliance Technology Group of New Orleans. This two-pronged, web based compliance software solution gives offshore operators the ability to:

- Apply the SMART 14C module to schedule and record all safety device testing as set out by the intense requirements of API RP 14C.
- Employ the SMART Plus module to manage all other compliance record-keeping and reporting items, including those contained in U.S. Coast Guard rules for Fixed or Floating facilities, as well as those required under EPA, DOT, DOI, ISO 14001 and other federal, state or corporate policies.

- Utilize SMART Files to store electronic copies of all other compliance documents, including vessel certifications, safety management certificates, and ship’s personnel certifications.

With SMART, operators do not miss tests, inspections or other compliance activities. Because it is web-based, the SMART system makes reports and other data available to all concerned parties, which assures corporate governance and accountability.

Significant changes in federal regulations resulting from the deepwater Macondo blowout and oil spill made it even more critical for Petrobras to have a leading-edge compliance system in place that can be updated immediately upon the handing down of any such new rules and policies. According to Compliance Technology Group, these current and future changes are being met as they are instituted by prompt updates to the SMART system’s software.

Founded in 2001, Compliance Technology Group provides the technical expertise necessary to design and build solutions to challenges in the oilfield environment.
AKER SOLUTIONS PROVIDED POWER, CONTROL UMBILICALS TO CASCADE AND CHINOOK DEVELOPMENT

Aker Solutions has been providing unique and innovative power and control umbilicals for the oil and gas industry’s deepwater developments since the early 1990s. The company has delivered more than 400 umbilicals totaling several thousand miles in length in some of the industry’s most challenging fields, from harsh environments to ultra-deepwater, high pressure conditions. The company provided dynamic power and control umbilicals and static infield umbilicals to Petrobras’ Cascade and Chinook fields.

Aker Solutions’ workscope for the Cascade and Chinook development included:

- Two dynamic control umbilicals;
- Two dynamic power umbilicals;
- One static infield umbilical similar in design to the dynamic control umbilicals;
- Two smaller infield umbilicals.

The umbilicals were manufactured at the company’s Mobile, Alabama, Middle Bay Port facility, a former naval base that was acquired and developed by Aker Solutions.

The dynamic power and control umbilicals for the Cascade field were about four miles long. The Chinook field dynamic power and control umbilicals were each about 14 miles long. The infield umbilicals ranged in length from under one mile to about two miles.

Unique designs

Aker Solutions’ umbilical designs are unique in the industry for several reasons. First, zinc coated steel rods are used for both weight and structural characteristics. The company employs a PVC matrix between the various components in which the elements are encapsulated. Additionally, Aker Solutions utilizes a patented carbon fiber rod that provides for axial stiffness without adding significant additional weight.

The carbon fiber rods reduce the global elongation of the cable and keep stress and strain at a low level, including in ultra-deepwater. Carbon fiber rods reduce the need for structural reinforcement on the host platform, reduced buoyancy requirements and increased ease of installation.

Prototype power and control umbilical

Aker Solutions built prototypes of the power and control umbilicals for testing prior to manufacturing the production lengths for the Cascade and Chinook fields. A variety of tests were performed on the umbilicals as well as on the components, including the medium voltage power cables. Testing also was performed due to the extreme water depths and high pressures anticipated to be encountered in those water depths.

Numerous lessons were learned from the prototypes and resulted in an improved manufacturing process. Aker Solutions modified its planetary cabling machines as a result of the prototype manufacture, which optimized the manufacture of the Cascade and Chinook umbilicals and will make future projects more reliable.

Steel tube control umbilicals

The dynamic control umbilical’s components included super duplex stainless steel tubes comprising three different sizes and pressure ratings. The range of tubes included a ¾-in. 15,000 psi tube, a ½-in. 15,000 psi tube and a ½-in. 10,000 psi tube.

Dynamic Power Umbilical - Topside in Aker Solutions’ Yard

Crush Test - Dynamic Power Umbilical
psi tube to carry a variety of hydraulic fluids, chemical injection, etc. Also within the control umbilical are low voltage quad cables for signal transmission as well as a fiber optic cable for telecommunications.

The cable and umbilical industry typically bundles the umbilical elements at steep helix angles where they are protected from excessive loading by armoring layers. Aker Solutions’ patented steel tube umbilicals utilize the capacity in the tube as the strength elements. The steel tube umbilicals are custom designed for specific projects and offer several advantages:

- Super duplex stainless steel tube is compatible with all commonly used hydraulic fluids and injection chemicals, including methanol;
- High crush load capacity for deepwater installation and improved fatigue properties;
- All tubes, electrical and fiber optic elements are individually protected and separated by PVC conduit, eliminating the need for separate armoring layers;
- PVC profiles provide multi-purpose functionality and protection and correctly space the internal elements in the umbilical cross section;
- PVC profiles absorb the impact energy efficiently through elastic deformation;
- Long and predictable service life.

Aker Solutions has the technology, capacity and capability to service the requirements of customers globally. The company’s state-of-the-art manufacturing facilities are located in the U.S. and Norway with engineering and project management capabilities at both locations. The facilities include horizontal bundling and extrusion machines, deepwater access to installation and transportation vessels, high capacity processing and storage carousels, and onsite welding and test facilities.

Aker Solutions’ manufacturing experience provides the industry with long step outs, ultra-deepwater, complex cross-sections with large numbers of elements, terminations, ancillary equipment such as bend restrictors, clamps, tethers, etc., and installation support through the company’s Subsea Lifecycle Services as well as EPC, FEED and concept studies.

**Loadout Dynamic Control Umbilical - Topside**
Since the first-phase development plan for its ultra-deepwater Cascade and Chinook project was unique in so many ways, operator Petrobras America insisted on employing high-performance drilling, evaluation, completion and production technologies from start to first oil.

Ranking high among the service providers and equipment suppliers throughout this process, including the production stage, was Baker Hughes.

Starting with well construction and completion, Baker Hughes optimization specialists and consultants lent their expertise in managing various drilling and completion parameters, including dealing with uncommon geological challenges, which necessitated sidetracking; maintaining controlled drilling to achieve equivalent circulating density; optimizing drilling windows with the aid of remote pore pressure management; using fit-for-purpose coring tools; and successfully utilizing LWD formation testing when wireline tools could not be run through impassable zones in the sidetrack.

Under a contract with Petrobras’ prime agent for subsea production equipment, FMC Technologies, Inc., Baker Hughes is supplying the project with six Centrilift XP™ seabed boosting electrical submersible pumping (ESP) systems and the associated topsides ESP management system. These are the first seabed horizontal ESP booster systems planned for the Gulf of Mexico.

Remote Pore Pressure Prediction, LWD-MWD Drilling Optimization, Special Coring and Wellbore Cleaning Join Subsea ESP Design for In-depth Participation

Remote pore pressure BEACONing

In the process of managing well stability and operational risks, well construction professionals conducted remote pore pressure management throughout the drilling sequence to help optimize mud-weight windows, among other parameters. Prediction was handled by a specialist at the company’s BEACON™ remote monitoring center in Houston. This was the first time real-time pore pressure data were used remotely for prediction in the deepwater Gulf.

To optimize the drilling process, CoPilot™ technology was deployed to provide real-time downhole monitoring of the drilling assembly. This optimization is based on comprehensive pre-well planning, a versatile downhole data acquisition and diagnostic tool with 14 sensors for real-time assessment of various drilling measurements, and thorough post-well analysis that delivers insight into wellbore conditions and provides increased bottomhole assembly reliability and improved wellbore quality with a high level of accuracy and detail.

Real-time CoPilot data were presented on a rig-floor display, and also were integrated into Baker Hughes’ BEACON service for transmission to Petrobras’ Houston office, and to the Houston BEACON Center.

In addition, Petrobras achieved one of the longest coring runs in the Gulf of Mexico for 12 1/4-in. hole size, which cut 360 ft of hole core. This successful application of advanced coring technology was accomplished through the use of the Hughes Christensen core bit (HT-406C) with 13 mm cutters and a built-in stabilizer. The cutters were designed specifically for both abrasion and impact resistance.

Working closely with Petrobras drilling engineers, Baker Hughes also used special trip-out procedures to assure that core recovery was maximized. Special lay-down procedures were used, as well, and non-rotating inner tube stabilizers were deployed in the core barrel to help open connections without core damage.

Finally, using Baker Hughes’ AutoTrak™ closed-loop rotary steerable drilling and evaluation system, integrated with MWD-LWD systems including the LithoTrak™ porosity tool and the OnTrak™ system for real-time positional certainty, Baker...
Hughes downhole measurement specialists applied the TesTrak™ LWD formation pressure-testing service in the pay zone, which was in the 12 ¼-in. section. After the section was drilled, the TesTrak testing service delivered real-time formation pressure and mobility data in 106 tests – the highest number of pressure tests made by Baker Hughes in a Gulf of Mexico reservoir – with a 97% success rate. Sealing efficiency averaged 93%, and reservoir pressure was in excess of 18,000 psi.

In the run-up to completion, Baker Hughes drilling fluids specialists used DISPLEX™ modeling and the MICRO-PRIME™ cleaning spacer for direct displacement of 5,000 bbl of 14.6 synthetic mud in one displacement train, which saved the operator two days of rig time, since it eliminated displacement of the riser independently from the rest of the wellbore.

For the Chinook No. 4 well, all spacers and brine were pre-mixed on shore to minimize manual handling at the wellsite, and the DISPLEX engineering software determined the correct pill volumes, pump rates and contact times. Additionally, the large volumes of fluid necessary for displacement required complex logistical management of the rig’s mud pits as well as the vessels to transport and transfer the fluids.

The result was notable cleanliness of the riser brushes, bush subs and tool joints, setting a new standard for wellbore cleanup operations.

In addition, Baker Hughes drilling fluids specialists provided filtration and completion fluids, including 12,000 bbl of 14.7 lbs/gallon of zinc bromide for the completion.

**Self-contained ESP cartridges**

The horizontal ESP boost systems provided to Petrobras by Baker Hughes placed the ESP system on a permanent base on the sea floor, providing ease of system change-out. This design allowed Petrobras to configure systems for redundancy and increase availability.

Such ESP booster systems offer a number of advantages over alternative methods, including deployment from a wide variety of vessel types and easy adaptation with existing infrastructure, providing Petrobras with economic solutions to maximize production from subsea wells.

With a constant eye on initial installation costs and subsequent repair costs, Baker Hughes and FMC combined their expertise in ESP systems and subsea production structures to meet the challenges presented by the extreme water depths and step-out distances existing at Cascade and Chinook.

The result was a modular, self-contained ESP cartridge made up of a horizontal, open-framed structure developed by FMC to house the production lines, two ESP systems, and the electrical penetration and fluid connections to tie into the subsea flowline.

Wellhead water depth and location influenced an important design goal, which was to meet the rate-pressure requirements for the defined flow conditions. Even though both fields flow naturally to the seabed, natural pressure could be inefficient due to water depth and distance to the floating production storage and offloading (FPSO) vessel. The step-out from wellhead to risers alone is unusually long – up to 13.5 miles.

For development of Phase 1, Petrobras installed booster systems for only two wells, with one twin-ESP cartridge per well, and a third cartridge held in reserve for possible intervention purposes.

From a production perspective, the Cascade and Chinook development plan included several technology innovations developed by Baker Hughes. Among these were:

- The first seabed horizontal booster system using ESPs in the Gulf, and the first time ever that Petrobras or Baker Hughes had installed such a configuration.
- The first use of an ESP-based booster system in ultra deepwater.
- The first application to run two separate ESP systems hydraulically in series, but powered and controlled in parallel from a single electric drive.

Baker Hughes Incorporated (NYSE: BHI) provides reservoir consulting, drilling, formation evaluation, completions, pressure pumping and production products and services to the worldwide oil and gas industry.
BW OFFSHORE PROVIDES FPSOs TO THE WORLD’S MAJOR DEEPWATER PROJECTS

BW Offshore is a leading global provider of floating production services to the oil and gas industry with a fleet of 15 FPSOs and two FSOs. BW Offshore has an excellent track record on project execution and operations, and more than 25 years of experience.

The company is represented in the major oil regions world-wide, with presence and operations across Asia Pacific, Americas, Australia, Europe and West Africa, and employs some 2,000 people worldwide. BW Offshore is part of the BW Group, one of the world’s largest maritime groups, and is listed on the Oslo Stock Exchange.

Strong Petrobras relationship
In 2007, BW Offshore was awarded the contract from Petrobras America for the FPSO BW Pioneer. The company managed the design, construction, installation and commissioning of the FPSO, and is responsible for its operation and maintenance in the Cascade and Chinook field. BW Offshore’s former technology division, APL, delivered a complete submerged turret production (STP) buoy and mooring system. The BW Pioneer is the first FPSO in the U.S. Gulf, and, at 8200 ft (2,500m) of water, is the deepest application for an STP buoy to date. The BW Pioneer is designed to disconnect and move by its own propulsion to safe waters in the event of a hurricane or other major storm.

While the BW Pioneer is the first FPSO in the U.S. Gulf of Mexico, the company has had the opportunity to work with Petrobras on pioneering projects in Brazil. BW Offshore delivered the first FPSO to Petrobras, the BW Cidade de São Vicente for the Tupi field, one of the largest fields in Brazil, through a fast track conversion project in 2009. Engineering work, purchasing phase and a high quality commissioning was completed within 335 days only.

BW Offshore also is converting the FPSO BW Nisa for the Papa Terra project joint venture which consists of Petrobras (operator) and Chevron. This contract was signed February 1, 2010.

Through its acquisition of Prosafe Production in 2010, BW Offshore now operates one additional FPSO for Petrobras: the Cidade de São Mateus that started production on the Camarupim field in October 2009.

Adapting through competence, in-house technology, solid project execution and operational excellence, BW Offshore meets its clients’ needs through versatile solutions for offshore oil and gas projects, and can deliver FPSOs as the preferred production solution in the development of ultra-deepwater oil fields.
DEUTSCH DEVELOPED INTERCONNECTION SYSTEM FOR CASCADE AND CHINOOK PROJECT

Deutsch has a long illustrious history going back to 1938 when the company was created. It designs, manufactures and sells connection systems in three main segments – industrial volumes connectors for the transportation sector, high tech connectors for aerospace, transportation and heavy industries; and top technologies for extreme connections in offshore. Deutsch develops a variety of interconnection solutions for harsh environments and it has an extensive research and development laboratory for fiber optic, signal and power connection systems.

The company, with around 3,000 employees globally and $561 million in turnover in 2010, was bought by French company, Wendel Investment, in 2006. Deutsch is headquartered in New York and has manufacturing and sales centers in a dozen countries including China, India and Israel. Its offshore operation, which forms a major link with subsea system providers and oil and gas operators, is concentrated in Le Mans, France to address topside, subsea and downhole areas. The company recently opened a facility in Houston, dedicated to offshore activities, to develop a competence center for signal connectors and to offer a stronger local technical support to its customers.

Deutsch experience and capabilities

Deutsch was a key partner to oil companies since the beginning of the subsea processing and boosting industry. Starting in 1984, the company developed a subsea mateable connector installed on a subsea multiphase pump, which was tested in the Fusa fjord, in Norway. This testing led to the patent of the helico-axial multiphase pump principal, now used by key major players in the subsea pumping and boosting market.

Following its first power project in a subsea environment, Deutsch worked on several subsea projects offshore Norway, and around the world during the 90’s and early 2000’s.

Deutsch is addressing three connectors markets, power, signal and optical, on a system level view, and is covering all applications, from downhole to subsea, to provide its clients a full solution for all connection systems in the harsh subsea environment.

Cascade and Chinook project

Taking advantage of the different technologies available within all of the company’s divisions, FMC Technologies awarded Deutsch a feasibility study for a high voltage (HV), high differential pressure (HdP) penetrator to be used on the Cascade and Chinook fields. This HV HdP penetrator is one of the key components of the overall subsea boosting system, as it allows use of the seabed ESP based pumping system. The penetrator is required to handle the deepwater requirement, and the extreme pressures and temperatures from the well stream.

Following this feasibility, the overall HV wet mateable connection system, developed and qualified to the latest industry standards, were awarded to Deutsch by FMC Technologies.

The scope of work consisted of three different tasks:

- Design, manufacture and qualify an HV HdP Penetrator system, including interfaces towards the pump internals interfaces, and interfaces towards the overall pump cartridge design and HV harnesses;
- Design, manufacture and qualify a splitter box, which allows the supply of power from one power triad in the umbilical to two subsea pump units.
- An EPC contract for the overall HV connection system, including power distribution unit connectors, HV flying leads and pump harnesses subassemblies, and all necessary accessories, such as test connectors, spares, etc.

The Cascade and Chinook project was a unique opportunity to demonstrate again Deutsch’s capability on the HV power connectors market, as well as for high pressure, high temperature applications. It also demonstrates the company’s capability of handling large scale projects, including engineering, manufacturing, testing and on-site services.

DEUTSCH
27628 Commerce Oaks Drive
Conroe, Texas 77385
Tel: +1 713 623 1925
Fax: +1 713 344 1418
Email: offshore@deutsch.net
Website: www.deutsch.net
To save on precious rig time during completion of the Cascade and Chinook wells, Petrobras contracted with Devin International to provide a number of its specialty completion and testing tools, along with various handling equipment, for installation aboard Seadrill’s West Sirius and Transocean’s DP drillship Discoverer Deep Seas during the completion phase.

Foremost of these installations was Devin’s innovative new Transfer Bail Assembly Spreader System (T-BASS), which replaces conventional methods for transferring a subsea test tree assembly from the offline rotary to the main rotary in a dual-activity derrick such as that found aboard the Discoverer Deep Seas. This new device provides the ability to lower the entire completion string through the rotary table on elevator links instead of the conventional sling transfer method.

The conventional method for transfer of the test tree assembly can take 10 to 12 hours to complete. However, use of the T-BASS system has reduced the time required to about 1.5 to 2 hours, allowing significant savings to the operator in terms of rig operating time — and rates.

Modifications to Devin’s patented Bail Assembly Spreader System (BASS) were proposed and overseen by Timothy Bedore of Deep Water Solutions. The new “T-BASS” with ported lift sub design was manufactured by Devin to provide a safer, more efficient way to transfer a subsea test tree aboard a dual activity

---

**DEVIN INTERNATIONAL AND DEEP WATER SOLUTIONS PROVIDE T-BASS SUBSEA TREE TRANSFER SYSTEM**

Equipment, including Patented Surface Test Trees and All Handling Tools, Installed aboard Discoverer Deep Seas Drillship and West Sirius semi-submersible

Designed by Devin International in cooperation with Deep Water Solutions, the T-BASS allows for full use of the offline rotary, increasing offline productivity and greatly reducing rig downtime vs. conventional methods.
vessel. According to Devin officials, use of the T-BASS allows for full utilization of the offline rotary, increasing offline productivity and significantly reducing rig downtime versus conventional methods.

The T BASS attaches to the forward block via elevators and elevator links. A ported lift sub with an integral pad-eye is torqued to the top of the subsea test tree. The main winch line of the T-BASS is then attached to the pad-eye by an 85-ton clevis. The rig’s aft block and forward block are raised to a pre-determined height, while paying out on the T-BASS winch. The subsea test tree is raised on slings by the aft block. The PRS is attached to the assembly and used to stabilize the SSTT during travel. The aft block is lowered while paying in on the T-BASS winch to transfer the SSTT. Once transferred to the forward rotary, the elevator located at the bottom of the T Bass assembly is then closed onto the ported lift sub so that the subsea tree can be lowered into the main rotary on elevator links.

**Patented test trees**

In addition to the T BASS assembly, Devin also provided its patented Surface Test Tree for intervention for completion and flow back operations during the Chinook well completions. The two tools are similar in design, with the exception that the Dual Mini is not used during flow back operations.

According to Devin, the size and weight of these test trees are less than half of those of similar tools, even though they have the same inside diameter and pressure rating. These features help to provide quicker, simpler and safer rig-up.

On the Chinook wells, Devin rigged up long bails in conjunction with the Dual Mini and Surface Test Tree. These bails provided a work window to accommodate wire line operations. Devin has the largest supply and variety of elevator bails in the Gulf of Mexico.

On the Cascade well, Devin supplied the stabilizer in conjunction with an existing lift frame to provide stability in the event of bad weather. Additionally, Devin supplied a skidding system as a contingency for easily moving a coiled tubing reel into place when it is necessary to do so.

**Top grade ‘extras’**

Premium thread safety packages were used on all wells, including safety valves, inside BOPs and pump-in subs. These tools all were equipped with specialty connections, which eliminated the need for additional crossovers.

In addition, since most of the handling tools necessary for Devin equipment were not standard rig inventory items, the company supplied handling gear such as bails and elevators from its large inventory warehoused in Devin rental service points along and near the Gulf Coast.

Having begun as a tool company specializing in casing and coiled tubing support, Devin expanded its tool support capability to provide difficult-to-find tools such as elevator bails and coiled tubing lift frames. It also expanded into providing handling tools and other equipment required for deepwater projects, including elevators for landing surface trees and lift frames designed to provide motion compensation between service equipment and work strings.

In 1997 DEVIN International, Inc. was formed with DEVIN Rental Tools and DEVIN Manufacturing as subsidiaries. In 2008 DEVIN International, Inc. became a wholly owned subsidiary of Greene’s Energy Group LLC.
Petrobras America Inc. is using Emerson Process Management’s integrated Roxar multiphase measurement and subsea sensor systems to help optimize production in the Cascade and Chinook fields in the Gulf of Mexico.

The latest deployment is the culmination of a growing, long-term relationship between Emerson and Petrobras, both upstream in the form of Emerson's Roxar measurement solutions and downstream through Emerson’s PlantWeb digital plant architecture.

In the Cascade and Chinook fields, the Roxar subsea Multiphase meter is providing accurate and continuous on-line monitoring of the flow rates of oil, water and gas in the subsea well streams. In addition, the combined sand erosion and pressure and temperature sensor systems are providing valuable, real-time production information on the reservoir, helping Petrobras meet challenges such as sand erosion and other threats to subsea infrastructure, as well as ensuring each well is operating at its peak potential.

**A real-time** multiphase measurement and subsea sensor system.

**A challenging environment**

Located in 8,200-8,800 ft (2,500-2,680m) of water, both the Cascade and Chinook fields come with a number of challenges.

In deeper water depths and high flowing pressure and flow rates, the wells and accompanying pipelines are vulnerable to saline and unchecked water that can impact the well’s production capabilities significantly. Sand can also clog production equipment and has the potential to erode completion components, impede wellbore access and interfere with the operation of downhole equipment.

Other production variables that need to be monitored include gas coning (the change in oil-water contact or gas-oil contact resulting from drawdown pressures during production), density and flow characteristics, and pressure and temperature information.

Taking into account these and other reservoir uncertainties, a phased development of the fields is taking place. Phase 1 (consisting of two subsea wells
in Cascade and one subsea well in Chinook) has the goal of analyzing initial reservoir performance in order that increased production and flow assurance can be secured in the future.

**Roxar subsea Multiphase Meter and Roxar SenCorr SEPT Sensor System**

Emerson’s Roxar solutions are providing critical, real-time information to Petrobras on its wells’ capabilities during production.

The Roxar subsea Multiphase meter is providing Petrobras with accurate flow rates for gas, oil and water, important information to track the development of gas coning, water breakthrough, flow conditions in the reservoir, indications of residual oil and even reservoir zone interconnectivity.

The meter incorporates a Dual Velocity™ method which calculates phase fractions based on capacitance and conductivity measurements. It uses a measurement principle that can handle and accurately describe complex flow regimes so that appropriate multiphase flow models can be applied and can handle all types of flow regimes, essential in the deep waters of the Gulf of Mexico.

In the case of the Cascade and Chinook fields, a subsea retrievable canister houses the meter’s electronics and flow computing modules. The result for Petrobras is low and cost-effective maintenance with limited subsea intervention requirements, high flow measurement availability, easy installation, and a simplified subsea structure design.

The Roxar subsea Multiphase meter.

**The Roxar combined sand erosion and pressure and temperature sensor.**

The Roxar subsea SenCorr SEPT sensors, which are approved for ultra deepwater installations of up to 15,000 psi, are providing valuable real-time information for Petrobras on the subsea wellhead in terms of sand erosion, pressure and temperature. Operating on the ER (Electric Resistance) principle, four independent sensing elements measure increased element resistance as they are exposed to sand erosion. The sensors require no calibration, are unaffected by flow and mechanical noise and can interface with all major subsea electronic modules.

**Generating value from the data**

With so much raw data generated from the Roxar instrumentation, it is essential that this data is transformed into valuable decision-making information.

To this end, Emerson has developed a new comprehensive field monitoring system, Roxar Fieldwatch (although not installed on the Cascade and Chinook fields). Roxar Fieldwatch integrates the Roxar monitoring instruments within a single, windows-based system, providing a complete picture of the reservoir. The scalable architecture also allows remote connectivity and enables multiple users to access the same data and instruments.

At the heart of the new system is the Field Server, which consists of algorithms and models for data validation, data conditioning, smart alarm handling and virtual instruments. Real-time sensor data is fed into the calculator and results are mapped back into the server before being converted into visualization tools for viewing and analysis.

**Meeting Offshore Challenges Worldwide**

The value Emerson is adding to the Cascade and Chinook fields is just one example of the prevalent role Emerson and its Roxar solutions are playing in offshore operations today.

From the Gulf of Mexico, to other deepwater developments in regions such as offshore Africa and the Norwegian Continental Shelf, Emerson Process Management is today playing a crucial role in flow assurance and ensuring that oil and gas reservoirs operate to their very highest potential.
FMC Technologies provides new solutions for Cascade and Chinook fields

FMC Technologies was awarded a contract by Petrobras America in October 2007 to supply subsea systems for the operator’s Cascade and Chinook field developments, which will produce from ultra-deepwater wells targeting the Lower Tertiary trend in the U.S. Gulf of Mexico.

This development has led to several industry firsts, including the deployment of a novel subsea pumping system developed by FMC to be installed horizontally on the seabed.

FMC met the challenges of this project by providing the technologies and solutions to address issues such as the ultra deepwater depth of up to 8,900 ft, the wide range of variation of flow and pressure that the pumping system must accommodate, thermal insulation and flow assurance requirements, long offset distances to the FPSO and data monitoring when the FPSO is disconnected.

FMC’s scope of supply included:
- Four enhanced horizontal subsea trees (EHXT) rated at 15,000 psi;
- Three, 4-slot manifolds;
- Two pump bases;
- Three pump cartridges, each containing two electrical submersible pumps;
- Eight jumpers and 16 jumper kits;
- Subsea control modules with multiple electrical and hydraulic modules;
- Subsea Data Acquisition System modules;
- Topside controls including Master Control Station, subsea power and communication unit, and radio link ESD controls;
- Medium voltage power system with variable speed drives and controls for the subsea pumping system.

Unique, innovative horizontal pumping system

The Cascade and Chinook pumping system is a world’s first. The innovative concept was conceived by Petrobras, with FMC Technologies developing the original concept and performing detailed engineering and construction. The unique design uses electrical submersible pumps that are installed horizontally on the seabed rather than placing the pumps in a producing well or in a caisson well as is common in conventional designs.

FMC’s scope of supply included the specification, design, manufacture and procurement of all components, as well as the qualification of the complete subsea pumping system. FMC also specified, procured and integrated the 6 kV medium voltage variable speed drive (VSD) and VSD module in the FPSO, the medium voltage connection systems, pumps and control system.

The subsea pumping system has several purposes, including to maintain production flow of hydrocarbons after the pressure within the wells has declined. The subsea pumping system will also maximize the volume of recovered reserves and keep the pressure and flow at the best possible levels for optimum production and flow assurance.

The horizontal pumping system is designed for the pumps to be installed on the seabed and away from the wells. The system comprises two pump bases, one for each field, located adjacent to each drill center and installed in 8,500 and 8,900 ft of water depth, respectively. Each base accommodates two pump cartridges that are mounted horizontally. Each 90-ton pump cartridge includes two 850 horsepower electrical submersible pumps that are capable of pumping up to 20,000 barrels of oil per day from several wells with a maximum offset distance of 12 miles to the FPSO. The cartridges also include recirculation loops that allow operation in a wide range of flow scenarios and optimize pump performance.

If necessary, the design allows a pump cartridge to be removed for repair or replacement without requiring a well intervention or well shut in to be performed, both of which can potentially damage a well and reduce potential pro-
duction. Additionally, the cartridges can be removed for refurbishment or pump replacement and reinstalled using a smaller and less expensive service vessel rather than requiring an expensive deepwater drilling rig.

Extensive qualification testing was performed on all critical components and is being performed on the complete pumping cartridge prior to installation.

**Insulating pipe and flowline components in high pressure, low temperature environments**

Another challenge that was overcome by FMC Technologies was providing an adequate thermal insulation system to operate in the high hydrostatic pressure and low temperature ultra-deepwater environment. FMC’s Novolastic™ HT thermal insulation has proven itself in such operating environments. Novolastic’s thermal insulation has unique properties that differentiate it from other types of insulation. The most important of these is its unique superior tensile elongation properties that allow thermal or mechanical expansion or movement of piping without cracking or breaking.

As a result of its proven performance, all of the Cascade and Chinook subsea systems, whether supplied by FMC or other vendors, used Novolastic™ HT insulation for the harsh deepwater conditions.

**Testing prior to load out**

FMC’s scope of supply for this project resulted in one of the largest deliveries of subsea equipment from the company’s Houston operation. The load out began in August of 2009 and comprised two manifolds and two large pump bases, one each for the Cascade and Chinook fields.

Prior to the load out, FMC conducted a series of system integration tests (SIT) and factory acceptance testing (FAT) of equipment destined for the Cascade and Chinook fields. The testing verified the connectivity and functionality of the system in the same configuration as when it would exist after being installed on the seafloor.

The testing involved two phases, each with a number of steps. Performing the tests required several installation engineers, service technicians, project managers and project coordinators. About 4,000 man-hours of work were involved and all of it was conducted without any safety issues occurring.

FMC Technologies’ engineering experience and expertise was the primary reason for being selected by Petrobras America to supply the crucial subsea equipment for the innovative and challenging Cascade and Chinook development.

FMC met and overcame every challenge with many innovative and unique solutions. The end result will be a successful project that includes numerous industry firsts, establishing a pathway for future deepwater and Lower Tertiary developments.
GRANHERNE SERVES AS ‘OWNER’S ENGINEER’ FOR PETROBRAS’ CASCADE AND CHINOOK PHASE 1 EPS

Once Petrobras America drilled the wells for the Cascade and Chinook fields and weighed the alternatives for an early production system, they acknowledged the necessity for having an independent third party to conduct technical due diligence for accountability among technical and build contractors involved to assure that project specifications would be met.

To serve in this important role – as the “owner’s engineer” – Petrobras chose the marine group of Granherne, a wholly owned subsidiary of KBR, Houston.

Both KBR and Granherne are engaged extensively in providing engineering services to producing companies operating in the Gulf of Mexico, particularly in deep and ultra-deep water, as well as to those operating in other offshore petroleum provinces around the world.

In its own right, Granherne is a leading offshore engineering consultancy. The company, along with its parent, has been involved in the design, construction and implementation of numerous ground-breaking deepwater floating production systems, including projects for Petrobras off Brazil.

For first-phase early production at Cascade and Chinook, which, due to the extreme water depths involved, Petrobras determined that a seafloor gathering and processing system serving an FPSO, Granherne provided technical support for design modifications to the FPSO would be the appropriate method to develop the fields.

As the owner’s engineer, Granherne played a key role in the run-up to installation of the FPSO.

A series of analytical software tools was used to study the plans set forth by the FPSO provider to give Petrobras another degree of assurance that the FPSO hull and mooring and offloading system provided met their specifications. Granherne also helped to certify that because they were going to be placing the first-ever FPSO in the U.S. Gulf of Mexico, that Petrobras and its contractors and subcontractors were in compliance with all government rules and regulations covering the EPS.

Its engagement in conceptual and front-end designs for deepwater projects around the world has enabled Granherne to develop a comprehensive deepwater knowledge base. Granherne makes reality checks at key stages of project design to ensure that system operability, reduced downtime and maximum production rates are achieved.

Independent evaluation
Granherne does not supply proprietary hardware and thus is independent in its evaluation of solutions for the customer’s deepwater system designs. This includes the floating production facilities, the subsea architecture and the management of flow assurance, for which the company is a recognized industry leader.

Safety and risk-based design principles must be established at an early stage in the decision-making process. They help ensure that hazards are evaluated in a structured manner and eliminated where possible. Granherne works closely with operators, and is a leader in establishing risk-based designs, acceptance criteria and performance standards.

Granherne, a wholly owned subsidiary of KBR, is a leading front-end engineering consultancy for onshore, offshore and deepwater oil and gas developments with experience of more than 3,000 projects in more than 20 countries.
Halliburton successfully fractured the initial wells drilled for Petrobras’ Cascade and Chinook development by working with Petrobras engineers to provide the optimum treatment and products in the challenging high pressure Lower Tertiary formation in the Gulf of Mexico. Halliburton’s fracturing experience and expertise applied to these complex wells and its innovative stimulation products and solutions resulted in the successful fracturing jobs.

Logistics is a primary issue when fracturing Cascade and Chinook wells that target the Lower Tertiary formations. Because procurement of high strength proppants can have lead times of 4-6 months compared with 4-6 weeks for common proppants, the key is having the infrastructure to handle the volumes and the long lead times. Halliburton owns and operates storage facilities in Fourchon, LA, for just such long lead time products, enabling the company to procure the appropriate proppants and chemicals in the necessary volumes well ahead of the project’s execution date. This dedicated storage and vessel loading facility not only aided in a successful Cascade and Chinook fracturing job but will support Halliburton’s future Gulf of Mexico projects.

Halliburton optimally fractured the wells for the Cascade and Chinook development using its normal fracturing fluids pumped by the Stim Star III stimulation vessel. Wells targeting the ultra-deep Lower Tertiary formations can sometimes require high treating pressure that cannot be met using normal fracturing fluids. The low density of normal fracturing fluid can result in increased treating pressure at the surface, which could exceed the surface pressure capacities. Petrobras engineers were able to optimize the fracture treatment designs to eliminate the use of a weighted fracture fluid system. Although high treating pressure was not an issue on this project, Halliburton has on hand its proprietary DeepQuest® heavy weight fluid which enables fracpack and fracture stimulation without exceeding the safety limits of surface treating equipment and wellbore tubulars. The service can eliminate the need and costs for higher pressure equipment while also resulting in a safer operation due to lower required surface pressures.

Halliburton technology used to treat the Cascade and Chinook wells was its SandWedge® conductivity enhancer, which is used in conjunction with propped fracturing and chemically modifies the surface of the proppant grains. SandWedge helps maintain high well productivity for a longer time by stabilizing the proppant pack and formation interface to reduce the intrusion of formation material into the proppant pack. It also enhances fracture fluid clean up and reduces proppant settling to help improve proppant pack permeability.

The Cascade and Chinook project required fracturing three different zones in each well, which was performed by the 17,500 hydraulic hp Stim Star III stimulation vessel. The Stim Star III’s fluid and chemical capacities accommodated all of the fluids, proppant and gels for the fracturing jobs. As a contingency, Petrobras had a second vessel stand by on location with additional fluids that could be transferred to the Stim Star III if necessary. A vessel-to-vessel transfer was performed when the standby vessel had to return to port, providing Halliburton with fluid transfer experience for future projects if necessary.

Halliburton treated three zones in each of the first phase Cascade and Chinook wells. Other Lower Tertiary projects call for treating as many as five zones. The company’s experience and planning, including for certain contingencies it envisioned, assured a successful Cascade and Chinook treatment during the first phase and for subsequent wells. Its additional experience gained treating high pressure Lower Tertiary wells will result in successful future projects.
JUMBO OFFSHORE PLAYS LEADING ROLE IN INSTALLATION OF FREE-STANDING HYBRID RISERS, BUOYANCY CANS AT CASCADE AND CHINOOK

Pre-project outfitting with new Deepwater Deployment System gives its heavy lift vessel Fairplayer the ‘muscle’ to break own record with 700-ton-plus offshore lifts

For the production risers employed at Petrobras America Inc.’s Cascade and Chinook ultra-deepwater fields, Technip USA, EPIC contractor, chose Jumbo Offshore to support transportation and installation of the project’s five Free Standing Hybrid Riser (FSHRs) comprised of four 7 inch ID units for liquids production and one 6 inch ID unit for handling natural gas export.

The Cascade and Chinook FSHRs are the deepest ever installed, as well as the first in the Gulf of Mexico to be connected to a Floating Production, Storage and Offloading (FPSO) vessel. Installation took place during the period August-December 2009.

Today, various iterations of FSHRs are being selected more often for floating production systems, particularly those located in more than 6,000 ft (2,000 m) of water. In the case of Cascade and Chinook, the risers are connected passively to the FPSO, the BW Pioneer. The “hybrid” feature of the system is that the steel riser pipe held standing by the buoyancy can is attached to the floating host by flexible jumpers. For the case of Casade and Chinook the host is the first turret moored FPSO in the GoM which allows for “weathervaning” when connected to subsea risers and permits for FPSO disconnection and sail-away off location in the event of hurricane or tropical storm.

Jumbo Offshore’s heavy lift vessel Fairplayer installs one of five enormous buoyancy cans for Free Standing Hybrid Risers at Cascade and Chinook project.

Each riser is equipped with a large buoyancy can that provides the required tension. Each buoyancy can is composed of individual chambers filled with nitrogen gas to ensure that the failure of any one of the chambers will not compromise riser operations.

DDS system extends lift vessel range

As part of its role in the riser installation, Jumbo Offshore mobilized its DP2 offshore heavy lift vessel Fairplayer to Rotterdam, where it installed the company’s Deepwater Deployment System (DDS), which consists of two deepwater winch systems that feed the main hoist blocks of the vessel’s two 900-ton mast cranes. With the DDS, Jumbo Offshore crews can lower structures to water depths of more than 10,000 ft (> 3,000 m). For the Cascade and Chinook project, the cranes were reeved to a 14-falls configuration to work safely in water depths of more than 820 ft (250 m) with an 800-ton hook load.

Once prepared for the project, the Fairplayer was dispatched to Technip’s Pori, Finland, fabrication yard to transport the custom-built buoyancy cans to the two Cascade and Chinook fields centers. There, it met up with Technip’s pipelay/construction vessels Deep Blue and Deep Pioneer for the riser installation procedure.

The Fairplayer’s scope of work at Cascade and Chinook included installation of the four 350-ton production
buoyancy cans, each 125 ft (38 m) long and 21 ft (6.4 m) in diameter, along with one slightly smaller can for the gas export riser.

Installation began with the Deep Blue deploying each riser in its entirety. The Fairplayer then moved in for a wet handshake. At a depth of 525 ft (160 m), each 7,545-ft-long (2,300-m) riser was taken over by the Fairplayer’s fore crane and placed in a hang-off structure for connection with its buoyancy can. Each assembly was then over-boarded, up-ended and lowered safely through the splash zone.

The Fairplayer broke its own record with these lifts, handling offshore loads of more than 700 tons.

While the assembly was lowered to a depth of 655 ft (200 m) by Fairplayer’s aft crane, each buoyancy can was de-ballasted by Technip’s Deep Pioneer. After positioning each riser, Technip made the connection with the riser’s foundation on the seabed, some 8,200 ft (2,500 m) below.

Safety, teamwork abound at Cascade and Chinook

For the Cascade and Chinook ultra-deepwater project, the close collaboration between Jumbo Offshore and Technip resulted in safe installation of both the buoyancy cans and the risers in winter conditions, with zero recordable incidents.

With its headquarters in Rotterdam, Jumbo Offshore is a business unit of privately owned Jumbo, which also includes the heavy lift shipping company Jumbo Shipping. Jumbo owns and operates 14 heavy lift vessels, including the Fairplayer and its sister vessel, the Jumbo Javelin, which can be used for subsea and offshore installation work. Examples are installing subsea structures and moorings for floating production systems and offshore wind farm installation. In addition to the DDS system aboard the Fairplayer, these vessels are equipped with two 900-ton Huisman mast cranes, a Kongsberg DP2 system, and exhibit very large deck and storage areas, making them versatile installation tools.

The company’s heavy lift vessels are contracted to “Lift, Ship and Install, All in One Go”, all in a smooth and continuous operation.
EARLY INVOLVEMENT BY NALCO CREATES VALUE FOR PETROBRAS AT ULTRA-DEEP CASCADE AND CHINOOK DEVELOPMENT IN GULF OF MEXICO

Nalco was chosen as the chemical solution and services provider for the Petrobras Cascade and Chinook project based on their track record of success in deepwater and ultra-deepwater (UDW) projects. When involved early in the capital expenditures (CAPEX) phase, Nalco maximizes value by taking a comprehensive view of the life cycle of the asset. This includes flow assurance, asset integrity and production optimization solutions; coupled with the ability to innovate in challenging environments.

The most significant new environment the industry faces is UDW production. Ultra-deepwater production is defined as oil and gas production in water depths greater than 5000 ft. These challenges include reservoirs with extreme pressures, high temperature, and produced fluids with flow assurance and asset integrity complexities.

Ultra-Deepwater Group

Nalco is concentrating fully on the new challenges associated with deep and ultra-deepwater operations and formed a dedicated Ultra-Deepwater Group, whose focus is:

- To work closely with production and engineering companies to identify, understand, and ultimately minimize many of the risks associated with ultra-deepwater production.
- To develop cutting-edge technologies that enable the industry to produce oil and gas safely, cost-effectively, and in an environmentally responsible manner.
- To develop innovative products that provide an order-of-magnitude improvement to the industry.
- To be a knowledge leader in ultra-deep water, allowing Nalco to facilitate new project development and operation from the front-end engineering design phase throughout the life of the asset.

The Nalco Project Management Team have created value for the Cascade and Chinook project by working together with Petrobras Operations and Engineering teams from the project design stage. In the past, chemical suppliers were brought into a project just prior to production start-up, which can result in missed opportunities to develop a comprehensive chemical management strategy for the asset.

Early involvement allowed the Nalco Project Management team to work closely with the Petrobras Operations and Engineering group to develop a production chemical program for the Cascade and Chinook fields. Initial chemical selection and screening required leveraging Nalco's experience in the ultra-deepwater Gulf of Mexico because Cascade and Chinook fluids were not available. Nalco R&D performed laboratory testing using analogous fluids based on similar composition. The testing provided the data required to develop a Chemical Management Program for Petrobras.

Nalco’s Project Management Team assisted Petrobras with reviewing Process and Instrumentation Diagrams (P&ID) related to the chemical injection equipment, overall subsea and production design. The Petrobras Cascade and Chinook project is the first FPSO in the Gulf of Mexico and Nalco leveraged global experience with FPSOs and utilized this knowledge to share experiences with Petrobras and incorporate lessons learned into the project.

From the P&ID and system review, Nalco identified and recommended improvements and changes. One of the major findings identified was a materials incompatibility issue with the chemical storage tanks in the FPSO hull. This finding and recommendation led to corrective actions prior to deployment of the FPSO from dry dock. Had this incompatibility not been discovered, chemical contamination
may have resulted, interrupting the chemical supply to the subsea applications. This interruption would have led to flow assurance issues impacting production.

Petrobras requested that Nalco’s chemicals meet Society of Aerospace Engineers (SAE) AS-4059, Class 8 specification or better for all subsea production chemicals. Nalco manufacturing plants undergo a strict certification program to ensure products meet SAE standards (Class 8, Bins B through F, or better) and these standards are consistent among plants and geographic regions. Every point in the manufacturing process is closely monitored to minimize risk of contamination. Finished products are sampled and certified to SAE standards. This ensures the products delivered to customer locations are within the cleanliness specifications.

Nalco experience has shown that manufacturing is only part of the requirement to deliver chemical on specification to the injection point. Dale Landry of the Nalco Project Management Team, said “the highest risk of contamination occurs during chemical handling and transferring in the offshore environment.” The Project Management Team reviewed the chemical transfer system and identified several gaps that would have prevented chemical cleanliness to the subsea injection points. Petrobras implemented Nalco’s design improvement recommendations to the subsea chemical system.

Pre-production scale squeeze program

The Cascade and Chinook fields are equipped with subsea trees. Conventional scale inhibitor squeezes, if applied after well completion, would be extremely difficult to accomplish due to the completion design. The Nalco research team, led by Myles Jordan, principal consultant for Oilfield Chemicals, was asked to evaluate and recommend a scale solution. Jordan developed a scale inhibitor program that would perform at water breakthrough and which could be applied as part of the completion program. Instead of a conventional downhole squeeze, Myles recommended that the product be injected during the acid perforation wash and linear gel stages of the well completion program, which involved fracturing the well.

Cory Neveaux, Nalco account manager, Oilfield Chemicals, said “the application of the scale inhibitor mixed with the acid and linear gel allowed it to be pushed far into the formation. Once adhered to the rock, its water solubility keeps it from desorbing from mineral surfaces until it comes into contact with produced water or brines.”

Scale inhibitor residuals will be collected to monitor the life of the scale squeeze in the formation.

Neveaux continues to support the Petrobras Cascade and Chinook fields during startup and through the life of the field. A continuous improvement process is in place to ensure that field condition changes are used to optimize and adjust the chemical program to maximize program efficiency.

Nalco is the world’s largest sustainability services company focused on industrial water, energy and air applications; delivering significant environmental, social and economic performance benefits to our customers. Nalco helps its customers reduce energy, water and other natural resource consumption, enhance air quality, minimize environmental releases and improve productivity and end products while boosting the bottom line.

Together, our comprehensive solutions contribute to the sustainable development of customer operations. Nalco is a member of the Dow Jones Sustainability Indexes. More than 12,000 Nalco employees operate in 150 countries supported by a comprehensive network of manufacturing facilities, sales offices and research centers to serve a broad range of end markets. In 2010, Nalco achieved sales of $4.25 billion. For more information visit www.nalco.com.
Due to its unequaled capabilities for ultra-deepwater offshore facilities transport and installation, Heerema Marine Contractors (HMC), was chosen by Petrobras to construct the unique pipe-in-pipe (PIP) flowlines in the Chinook field.

The operation was a crucial step in Phase I of Petrobras’ Cascade and Chinook deepwater development. The work, which at the time constituted the world’s deepest laying of PIP flowlines, was completed ahead of time and within budget.

Each of the Chinook flowlines is 12 miles (19.5 km) long, with a 14-in (36-cm) outer pipe and 9-5/8-in (24 cm) inner pipe. The lines are installed in water depths ranging from 8,000 ft (2438 m) to 8800 ft (2682 m) in the Gulf of Mexico.

In addition to the actual offshore flowline installation, HMC’s scope of work included design and fabrication of various flowline components. Among other operations, this included:

- The four pipeline end terminations (PLETs).
- All forgings (bulkheads, pull-out and hang-off forgings).
- Supply of vortex-induced vibration (VIV) strakes, anodes and coating.

According to Dick Wolbers, HMC project manager, the company’s focus on integrated pre-planning, coupled with the size and robustness of its offshore installation equipment, contributed significantly to the smooth progress of the operation.

World record for PIP flowlines

The Balder is equipped for deepwater pipe lay in the J-Lay mode for installation of both flowlines and production risers. It is equipped with the world’s largest J-lay tower.

The Balder was able to hoist the extremely heavy PLETs and 120-ft double-piped Chinook flowline joints into the J-lay tower with only the secondary blocks of its lift crane – an operation achievable only with the main blocks of other deepwater construction vessel lift cranes.

Safety record lauded

“But our greatest satisfaction from the entire project was completing 650,000 man-hours without a lost-time incident,” said Wolbers, “and that includes all hours worked by our subcontractors, as well.”
OSG PROVIDES SHIPS FOR FIRST U.S. FLAG GOM SHUTTLE TANKER SYSTEM FOR CASCADE AND CHINOOK

FPSOs served by shuttle tankers not a new technology, but Overseas Cascade and Overseas Chinook fill Jones Act, Oil Pollution Act rules for U.S. coastwise trade

Anticipating first oil produced from the Cascade and Chinook fields to begin loading into the FPSO Pioneer sometime during the first half of 2012, project operator Petrobras Americas made sure in early planning to have a proven, fast and economical way to offload the treated crude from the FPSO for transport to shore. They found it in the form of two U.S. Flag double-hulled shuttle tankers to be provided under charter by OSG Ship Management Inc., Tampa, FL.

Like the FPSO itself, the shuttle tanker operation at Cascade and Chinook is a first for the U.S. Gulf of Mexico. However, it is not all-new technology. More than 100 FPSOs currently are in use in other areas of the world, the first having been built for North Sea production operations in 1977.

OSG Ship Management, a division of the Overseas Shipholding Group, paid about $115 million for each of the 46,815-dwt vessels, built recently at the Aker shipyard in Philadelphia. When Petrobras chartered them, OSG arranged for conversion into shuttle tankers at the Detyens shipyard in Charleston, SC.

The tankers, christened Overseas Cascade and Overseas Chinook, are diesel-powered and are 600 ft (183m) long with a beam of 105 ft (32m). Each is capable of carrying up to 332,000 bbls and operating at more than 14 knots.

Filling the bill
The Overseas Cascade was handed over to OSG in March 2011. The second OSG shuttle tanker, Overseas Chinook, delivered to OSG in March 2011. Both are under long term charters that could run until 2018.

The vessels are compliant with both Jones Act and OPA 90 rules. They were built in the U.S., are registered under the U.S. flag, are at least 75% owned and operated by U.S. citizens, and are manned by a U.S. crew. And, as mandated by OPA 90, they are double-hulled.

To operate specifically with the Cascade and Chinook project’s FPSO vessel, OSG removed the fixed propeller propulsion systems on each ship, replacing them with Rolls-Royce (Kamew) 5,600-mm controllable pitch systems interfacing with Kongsberg control systems.

For each vessel, the Detyens yard fabricated and installed a tunnel in the bow followed by installation of a Rolls-Royce TT2400 bow thruster backed by a Caterpillar 2,250-kW generator, all interfaced with Kongsberg controls.

Finally, for working specifically with the FPSO Pioneer, an Aker Pusnes bow loading system (BLS) was assembled and installed on each vessel. This entailed installation of raised forecastle space to house it, along with connections to the tanker’s cargo system and an hydraulic system for a redundant power supply.

Minding the rules
According to OSG officials, under OPA rules all non double-hulled tankers operating in U.S. waters must be removed from service by 2015, which means that 25 of 84 vessels currently competing in U.S. coastwise trade must be phased out.

OSG Ship Management Inc. is a wholly owned unit of Overseas Shipholding Group, Inc. (NYSE: OSG), one of the largest publicly traded tanker companies in the world. It is a market leader in global energy transportation services for crude oil, petroleum products and gas in the U.S. and International Flag markets.
PetroQuip Energy Services, a Houston-based downhole flow control manufacturer and supplier, was asked to provide the majority of the accessories for the Chinook-4 and Cascade-4 required to produce the wells in 2010. This included all components in 13-CR Stainless Steel, to meet the client’s specifications.

Petrobras America, Inc. resourced PetroQuip Energy Services as the focal point for Cascade and Chinook wells. PetroQuip worked significantly with Petrobras to prepare Cascade and Chinook wells for production, providing standard API mechanical tubing, pup joints, couplings, crossovers, and blast joints. PetroQuip’s responsibilities included detailed design, materials procurement, quality control, manufacture, and post-fabrication inspection.

Not only did Petrobras America, Inc. use PetroQuip Energy Services as a source for tubular accessories, they also resourced PetroQuip for makeup and testing of primary and backup sub-assembly equipment, as well as inventory control while completing two wells simultaneously with shared equipment. While Petrobras required 100% backup on all equipment, the backup equipment on the first well became the primary equipment on the second. This equipment logistical support was maintained and monitored through PetroQuip Operations while working with multiple service companies.

Over the course of the project there was totaling some 14,600 ft of tubing and over 140 assorted components. Bottom hole pressures exceeded 18,900 psi in both wells. Even with these requirements, the project was successfully furnished on schedule for 2010 production thanks to the close communication and partnership between the teams.
In addition to standard API mechanical tubulars, PetroQuip also offers a full line of downhole flow control equipment, consisting of mechanical on/off sliding sleeves, one shot hydraulically actuated sleeves via tubing pressure, and hydraulically operated sleeves for smart completions.

The Annular Production Control Valve (APCV-II) is a sliding sleeve mounted on the production tubing, controlling communication between the annulus and the tubing. The internal sleeve can be shifted with either PetroQuip’s PB Shifting Tool or an industry standard Model B shifting tool. There are over 2,000 APCVs currently in service globally.

The patented Pressure Actuated Sleeve Shifting Tool (PASST) works with PetroQuip’s three-stage Annular Production Control Valve (APCV-III) controlling communication between the annulus and the tubing. The APCV-III shifts hydraulically once, then converts to a standard two-position mechanical sliding sleeve.

The Dual Line Valve (DLV) is a hydraulic sleeve that is operated from the surface using control lines. To open, pressure down one control line while taking returns up the second line. The DLV is ideal for a 2-zone, 3-line smart completion.

For more information on all PetroQuip products, please visit our website.
COMPETITION DIAGNOSTIC INNOVATION REQUIRED FOR COMPLEX COMPLETION CHALLENGES

Washpipe-conveyed Spectral PackScan was specifically designed by ProTechnics to meet the rigorous specifications of the Cascade and Chinook completion program.

ProTechnics is the world leader providing completion diagnostics services to the oil and gas industry. Our time tested and innovative tracer (isotope and chemical) and imaging (logging) products and services have gained a valued position among completion and subsurface engineering teams. Above all, the deepwater Gulf of Mexico challenges have required innovation to keep up with the increasing demands of depth, pressure and the complexity of the completions. ProTechnics has stepped up by providing trusted advancements and tool designs that have kept pace with these challenges.

Cascade and Chinook Design Challenge

As early as three years before the first completion was pumped, the Petrobras design team invited ProTechnics engineers into the project to assess the complex completion requirements. As in most completions in the deepwater Gulf, the operator was interested in being able to place the ProTechnics Spectral PackScan logging tools in the washpipe for economical and timely assessment of the frac pack operation. With ProTechnics technology on board, the engineering team had the unique ability to assess the quality of the frac and, more importantly, the integrity of the annular pack. Armed with this information, critical go-forward decisions are routinely made, such as whether to perform a top-off job, deploy a pack vibrator or, in the worst case scenario, actually pull the completion and re-frac pack the well. In many cases, the production teams are subsequently advised as to pack quality that would warrant careful consideration of the pack during production.

Subsurface completion designs in the Cascade and Chinook project added a new challenge: how to obtain this vital completion diagnostic information in a complex multi-stage single trip operation. Because the Spectral PackScan is a memory tool with finite memory capacity, the tool design engineers at ProTechnics went to work to provide the necessary downhole memory required for this project. Tool modifications specific to this application gave the engineering team the confidence that the washpipe-deployed Spectral PackScan would meet their downhole time requirements. The project was a GO.

Technology Description

The Spectral PackScan service is a versatile and economical combination spectral tracer log and a sophisticated gamma density annular pack evaluation tool deployed via the washpipe. With rig time at such a premium in deepwater offshore operations, washpipe-deployed tools are best-in-class decision points. During the frac pack operation, ProTechnics SpectraStim gamma tracers

Image above depicts an inadequate annular pack. Both the traced sand and the gamma density indicate that there is exposed screen section and no reserve gravel in the blank. Remedial top-off job performed.
ProTechnics was instrumental in providing Petrobras with the necessary completion evaluation data in a timely manner to ensure proper sand control completions on this project.

Ziad Haddad, lead subsurface engineer for Petrobras.

are injected in the proppant stages of the frac and annular pack. As the washpipe is being pulled across the treated interval, the spectral signature of the injected tracers is recorded into memory. Along with these tracer data, the packscan section of the tool is recording gamma signatures from a sealed source in the tool. Expert analyses of these two independent measurements quickly renders a complete picture of vital frac and annular pack information. Engineers can then determine the extent of the fracture height and proppant placement in the formation for future design changes and optimization. More important in frac pack operations is the timely assessment of the competency of the annular pack. Spectral PackScan is designed to provide this gamma density evaluation, which can accurately indicate where exposed screen and voids have occurred and precisely define the top of reserve gravel in the blank. Armed with this information, timely remedial action plans can be implemented.

Value Delivered
ProTechnics Spectral PackScan services were successfully delivered on all six frac pack stages on both the Cascade and Chinook completions. Examination of the post-treatment images allowed the Petrobras completion team to assess the quality of the frac pack operation such that timely critical path decisions were made. In two of the treatments, the Spectral PackScan revealed a less than acceptable screen pack where a successful top-off job was performed, providing the pack integrity necessary for long-term success of the completion. Other completions were examined by the team and found to be of high quality and would perform as designed for the expected producing flow conditions.

"ProTechnics was instrumental in providing Petrobras with the necessary completion evaluation data in a timely manner to ensure proper sand control completions on this project," said Ziad Haddad, lead subsurface engineer for Petrobras. Deepwater completions demand timely critical decisions to be made and engineering teams around the world are relying on completion diagnostics provided by ProTechnics to gain this advantage.

Image above depicts a quality frac pack. The traced sand (red/yellow) and the gamma density (magenta curve) both verify adequate gravel reserve in the blank and a competent pack across the screen. No remedial action required.
Cascade and Chinook are milestones in the development of ultradeepwater assets in the Gulf of Mexico, where the industry’s experience in Lower Tertiary, Wilcox trend reservoirs is still very limited. The initial development of Cascade, Chinook, and other ultradeepwater fields requires large capital investments, advanced technology, and the creative use of existing tools.

The financial risk is great. Beyond that, factors such as reservoir compaction, the production of sand, the reactivation of fractures, and other geomechanical processes affect the quality of the reservoir and integrity of the wells.

The 4D geomechanical model

“Understanding all of the drilling, completion, and production risks is a critical step in the engineering process,” says Jose Adachi, principal geomechanics specialist for Schlumberger. “To help evaluate these risks, Petrobras and Schlumberger Data & Consulting Services (DCS) built a comprehensive 4D geomechanical model for the Cascade field.”

The model includes the reservoir and the overburden up to the seabed, as well as the side burdens, underburden, and all major faults.

“We characterized the geomechanical properties of the rocks using a combination of log data, seismic velocities (acquired and processed by WesternGeco), TerraTek* geomechanics laboratory testing, and in-situ measurements such as minifracs and leak-off tests,” says Adachi.

The model was constructed in Petrel* and ECLIPSE* software. Rock properties and pore pressures were transferred to VISAGE* modeling software, a finite-element code that runs fully coupled simulations with the ECLIPSE reservoir model. The VISAGE software uses state-of-the-art numerical methods to calculate the stress and strain induced by production and injection. The computations can be performed at any time during the life of the field, which is why the model is called 4D.

“Our 4D geomechanical model of Cascade allows Petrobras and DCS to evaluate the risks of compaction, fault reactivation, and wellbore failure for the life of the reservoir,” Adachi says. “Preliminary results indicate a relatively low level of compaction, which is consistent with the high strength of the rock.”

The final integrity evaluation of the wells was performed using “sector models,” which are local grid refinements around selected wells. They include details of the casing, cement, and completion, which can also be modeled with the VISAGE software.

The 4D geomechanical model also predicted the porosity and permeability losses caused by compaction.

“That data helped further refine the ECLIPSE reservoir model,” Adachi says. “And we used the stress orientation and magnitude predictions to assess potential problems with the hydraulic-fracture completions.”

Record well completions

The first production wells for Cascade and Chinook include the two largest deepwater, high-pressure perforating
With gross perforation intervals of more than 800 feet and downhole pressures higher than 19,000 psi, completing and perforating the wells was a world-class challenge.

“We needed to perforate several intervals in one run to complement the single-trip multizone (STMZ) frac-pack system,” says William Sanders, Deep Water and Special Projects supervisor. “In a typical STMZ job, all zones are stimulated in a single trip.”

At Cascade and Chinook, perforating all the intervals with long gun strings and then frac-packing multiple zones in a single trip saved more than 67 percent of the rig time that would have been needed to perform conventional stacked frac-packs, which require several trips for each zone.

“One of the biggest challenges was managing the intense pressure inside the wellbore when the guns went off,” Sanders explains. “Perforating gun-shock loads are generated by sudden pressure waves in the completion fluid and stress waves in the structural components. The magnitude, duration, and timing of these waves depends on the design of the job, including the gun system, loading of the guns, number of shock absorbers, and the distance from the packers to the guns.”

The solution
For Cascade and Chinook, Sanders and the Schlumberger team selected a unique combination of tools that functioned as a true 25,000-psi perforating gun system. It included the 7-inch, 18 spf HSD* gun with PowerFlow* charges, 7-inch perforating shock absorbers (SXVA), and 7-inch eFire* redundant electronic firing head systems.

“The two wells at Cascade and Chinook represent the longest intervals ever perforated under extreme conditions of total depth, water depth, and hydrostatic pressure,” Sanders notes. “Our success extends the range of what is possible in the development of ultra-deepwater fields.”

*Mark of Schlumberger

7-inch 25,000 psi perforating systems were used to perforate the over 800 foot gross (over 400 foot net) perforation intervals on the Cascade and Chinook wells.
Seadrill, a young company with a long history and a modern rig fleet, completed the first well in Petrobras’ deepwater Cascade and Chinook field project. The drilling contractor’s West Sirius semisubmersible, rated to drill in up to 10,000 ft of water, also drilled the well’s top hole section.

The West Sirius, a newly built rig delivered during the second quarter 2008, set the blowout preventer (BOP) on the seafloor on Dec. 31, 2009, and disconnected from the well on May 3, 2010. During the four months on the Cascade well, the rig experienced 97% uptime. During 2010, the deepwater rig’s uptime rate was nearly 99%.

Building a young company

The company’s growth strategy is two-fold: ordering newbuild rigs and acquiring established drilling contractors with premium equipment and experienced rig personnel. Seadrill’s deepwater rig managers average 25 years experience while its drilling section leaders boast an average 27 years of experience. The company’s toolpushers average of 20 years experience. Its drillers have an average of 14 years experience.

Seadrill was established in 2005 when it acquired jackup rigs from Odfjell Drilling, drillships from Mosvold Offshore and ordered four new semisubmersibles on speculation. In 2006, Seadrill acquired Smedvig ASA, which had 35 years of experience in the global contract drilling industry at the time. Smedvig itself had acquired Dyvi Offshore and Robray Drilling, providing Seadrill with a modern fleet of advanced mobile drilling rigs and a strong market position in harsh environment, deepwater and dual drilling operations.

Smedvig also operated a fleet of tender-assisted drilling rigs, a niche market that Seadrill continues to grow, resulting in the company becoming the largest contractor of tender-assisted rigs in the world with a 53% share.

The company has not slowed its growth. In 2010, Seadrill acquired Scorpio Offshore, a company in which it had already owned a share. This purchase provided Seadrill with seven new jackup rigs and an entry into the Middle East market.

With this acquisition and the delivery of three newbuild jackups plus the purchase of an existing jackup in 2010, Seadrill became the largest operator of premium jackup rigs built after 2006.

Continuing the expansion of its deepwater rig fleet, Seadrill in early 2011 purchased Seadragon’s two new ultra-deepwater, high specification semisubmersibles under construction in Singa-
pore. Both rigs are scheduled for delivery in 2011. The rigs will be capable of drilling in up to 10,000 ft of water and feature larger operating areas, high load carrying capacity, and improved safety features.

At the end of 2010, Seadrill operated 44 rigs, including nine semisubmersibles, four drillships, 15 jackups and 16 tender-assisted rigs, including six semi-tender units.

The company is the second largest deepwater drilling contractor with 11 semisubmersibles and drillships with an average age of only three years. Seadrill also is the largest operator of tender-assisted rigs with the industry’s most modern fleet, comprising ten barge units and seven semi-tender units with an average age of ten years. Seadrill is the only company that operates semi tender-assisted rigs.

At year end 2010, Seadrill’s ambitious newbuild program comprises one semisubmersible, a sister unit to the West Sirius, two ultra-deepwater drillships rated to operate in up to 12,000 ft of water, five jackups capable of working in 400 ft water depths, and one semi tender-assisted rig.

Building a strong company
Seadrill’s rig fleet includes numerous rigs of the same class and design, providing a greater sample for lessons learned, as well as providing a standard across numerous rigs for parts availability, safety and training. An important aspect of standardizing across rigs is that customers know they have a backlog of trained rig personnel that can efficiently move from one rig to another with little or no additional training required.

Seadrill’s flat management approach is focused on efficiency by eliminating several management and supervisory layers. This management style brings the company’s executive and operational decision makers closer to its customers, resulting in quick decisions and proactively providing solutions.

The flat management approach also works on the company’s rigs. Each rig has a Rig Manager who oversees the rig operations with respect to the company and customers. The Rig Manager has a Rig Leader who handles the day-to-day rig operations and a Technical leader who looks after the asset. The Rig Manager also has a HR administrator and an accountant on his team for additional rig management support that in turn provides excellent response and support to the company’s customers. This Structure allows the Rig Manager to address and focus on the customer’s concerns.

De centralized structure
Seadrill’s decentralized organizational structure allows the company to be closer and more accessible to its customers and provide them with empowered local decision-makers with strong corporate coordination. The geographic-based organizational structure operating from four hubs provides a full suite of services and rig types with consistent service across asset types and regions.

Geographic regions include the Americas, based in Houston; Europe, based in Stavanger, Norway; Africa - Middle East, based in Dubai; and Asia Pacific based in Singapore. Three of the hubs feature technical centers of excellence: deepwater in Houston, harsh environment in Stavanger and jackup and tender-assisted rigs in Singapore.

Customer service is Seadrill’s primary focus, from its excellent rig uptime to its excellent fleet wide safety statistics to its streamlined and experienced management. This focus has enabled the company to grow quickly to become one of the industry’s top offshore drilling contractors with a presence in all of the major and important oil and gas regions, including the North Sea, Brazil, Africa, Middle East, Southeast Asia and the U.S. Gulf of Mexico.

Seadrill’s ambitious growth since its establishment only five years ago is phenomenal due to its business philosophy of buying and building. In early 2011, the company’s fleet totaled 55, including 44 operational rigs and 11 rigs under construction. More newbuild rigs are in the planning stages.

The company’s operational philosophy of delivering on its promise of excellent drilling, safety and environmental performance is the means to deliver on its goal of setting the standard in drilling.
Petrobras America awarded Technip two main contracts for the ultra-deepwater Cascade and Chinook development in the Gulf of Mexico. Technip’s work scope under the first contract comprised the engineering, procurement, construction and installation (EPCI) of five Free Standing Hybrid Riser (FSHR) systems for both the Cascade and Chinook fields. Under the second contract, Technip’s work scope included the Cascade infield flowlines and gas export pipeline. This contract also included:

- Welding of approximately 75 miles (120km) of 6-in. and 9-in. steel pipelines;
- Design and fabrication of 10 pipeline end terminations (PLET) and in-line tees;
- Installation of the pipelines and associated structures.

Technip completed its portion of the development project in only 28 months from contract award to final installation.

**A true international project**

Fulfilling Technip’s Cascade and Chinook EPCI contract truly was an international effort, bringing together engineering teams from the company’s offshore and subsea divisions in the United States, Brazil, France, Canada and the United Kingdom. Fabrication of the buoyancy cans and suction piles was performed in Pori, Finland. The flexible pipes were fabricated in Le Trait, France.

The company’s Houston engineering center handled the project management, engineering and procurement with an integrated team of 120 engineers. Houston’s engineering efforts were supported by a Design Verification team from Seal Engineering in France and technical assistance from teams in Brazil and the Offshore Engineering Division in Aberdeen, Scotland. Technip’s spoolbase in Mobile, Alabama welded the line pipes.

**Several firsts accomplished**

Technip’s portion of the Cascade and Chinook fields development produced several firsts. The project is Technip’s first ultra-deepwater installation, and the first tied back to a floating production, storage and offloading (FPSO) vessel.

In August 2009, the company’s Deep Blue, the world’s largest purpose-built ultra-deepwater pipelay and subsea construction vessel, successfully installed four foundation piles, two manifolds and two pump stations. Designed for the in-

---

**Free Standing Hybrid Riser (FSHR)**

---
Installation of all types of flexible and rigid pipe as well as umbilicals, the Deep Blue utilized the J-lay methods. Technip’s flagship vessel supports developments in water depths up to 10,000 ft (3,000m).

The vessel also installed five foundation suction piles for the FSHR system in October 2009. Four of the suction piles measured 83 ft long and 16 ft in diameter and one of the suction piles measured 68 ft long and 16 ft in diameter. These lifts represent the largest carried out by the Deep Blue up to that time.

Installation of the five free standing portions of the FSHR was completed in December 2009 utilizing a multi-vessel operation that included Technip’s Deep Blue and Deep Pioneer, and a heavy lift vessel under contract, the Jumbo Fairplayer. Designed for the installation of all types of flexible and rigid pipe as well as umbilicals, the Deep Blue utilizes reel-lay and J-lay methods. Also, Technip’s flagship vessel supports developments in water depths up to 10,000 ft (3,000m).

Safety first

Safety is a top priority at Technip. As a result of cultivating a safety culture at the company Technip North America received a safety award from Petrobras America, recognizing the safety performance of the Cascade and Chinook projects (Packages 5A, 5B and Flexible Supply). The award is for achieving 2 million man hours with:

- Zero lost time incidents;
- Zero recordable incidents;
- Zero environmental incidents.

Technip was one of four major contractors that participated in the 2 million man hours on the project.
Subsea 7 is one of the industry’s leading subsea installation contractors, boasting extensive deepwater and ultra-deepwater experience in the Gulf of Mexico and offshore Brazil as well as other major global markets. The company has performed a major share of Petrobras’ deepwater installation projects offshore Brazil during its 30 plus year relationship with the operator. That relationship, coupled with Subsea 7’s deepwater experience in the Gulf of Mexico, ideally suited the company for work on the operator’s Cascade and Chinook project.

Subsea 7’s workscope for the Cascade and Chinook development included fabrication of 10 jumpers and installation of six of these along with installation of two dynamic control umbilicals (Cascade at 4.75 and Chinook at 14 miles long), three static control umbilicals, an infield signal cable, seven steel tube hydraulic flying leads, and 25 electrical flying leads.

Installation was performed by Subsea 7’s pipelay and construction vessels Skandi Neptune and Seven Seas. The vertical lay systems on the Skandi Neptune and the Seven Seas were ideally suited for the deepwater Cascade and Chinook project. The Skandi Neptune, based in the Gulf of Mexico, performed the first phase of the installation, conducting pre-lay surveys and installing umbilical termination mudmats, three static umbilicals, the infield cable, seven steel tube hydraulic flying leads, and 25 electrical flying leads.

One of six jumpers installed for Cascade and Chinook.

The project was fully manned from Subsea 7’s Houston office, which maintained a close working relationship with the Petrobras America team, also based in Houston.

Subsea 7 successfully performed the control system subsea equipment component installations while overcoming several challenges. Among these were the ultra-deepwater depths ranging from 8,200 ft (2,500 m) to 8,800 ft (2,682 m), 13 miles of furrow along the Chinook umbilical lay route, and laying static umbilicals and cables under the submerged turret buoy mooring lines. Subsea 7’s installation engineering team also played a key role in Petrobras’ successful execution of the first subsea umbilical pull-in to a submerged turret buoy.

All of Subsea 7’s operations were successfully completed against an extremely tight timeline as well as sharing the installation site with the simultaneous operations of drilling rigs, stimulation vessels and other installation vessels. The Subsea 7 project team and the vessels’ crews demonstrated the professionalism and engineering expertise that has become synonymous with the company’s vision and what has come to be expected by its clients.

SUBSEA 7
10787 Clay Road
Houston, TX 77041
Tel: 713-430-1100
Fax: 713-830-3842
E-mail: NA.Communications@subsea7.com
Website: www.subsea7.com
THREE TENARIS PIPE MILLS SUPPLY CUSTOM TUBULAR SYSTEM FOR CASCADE AND CHINOOK

Research and Development capabilities help assure Petrobras of high-performance, riser, pipeline systems and services for the ultra-deepwater, HP-HT project.

When Petrobras planned the largest project it has ever done outside Brazil – at Cascade and Chinook – the extremely wide-ranging requirements for high-performance, ultra-deepwater tubular systems for both fields called for a supplier with R&D capabilities as well as integrated manufacturing facilities capable of delivering finished products efficiently and under simplified logistics.

To supply this complete system Technip, Petrobras’ EPCI contractor, chose Tenaris, whose many decades of tubular manufacturing know-how and integrated global network of manufacturing centers assured on-time delivery of both rigid pipe and bended tubulars.

Seamless pipe for the Cascade and Chinook production system, which encompasses five Free Standing Hybrid Risers (FSHRs), gas export lines and insulated infield flow lines and scores of critical pipe bends, was provided simultaneously by Tenaris pipe mills in Mexico, Italy and Argentina.

Location of both fields in ultra-deep water – 8,887 ft (2,740 m) – where the high-temperature (250 deg. F), high-pressure (19,000 psi) production stream called for high-strength sour resistant, and coated pipe, Tenaris’ R&D capabilities allowed the design and development of 18,000 tons of rigid pipe for the FSHRs and the pipe-in-pipe flowlines, as well as internally tensioned, high-strength rods for umbilicals. Design and manufacturing of the high steel-grade induction bends, which Petrobras described as one of the most critical products in the project scope, also benefited from Tenaris’ R&D capabilities.

Endures deepwater, HP-HT environment

The pipe-in-pipe flowlines and gas export lines from the three wells currently producing at Cascade and Chinook were designed by Tenaris to withstand the extreme deep-sea environment and demanding installation conditions.

Working alongside with world-class bending manufacturers to provide high-quality bending solutions, Tenaris supplied pipe for both jumpers and bends to support the seafloor applications connected to the development’s Floating Production, Storage and Offloading (FPSO) facility.

Tenaris customers obtain a wide range of bend geometries, as well as total design flexibility with customized radius and angle – in addition to conventional 45- and 90-deg. bends. Hot induction bending followed by full off-line quenching and tempering is the preferred process for HP-HT, ultra-deepwater steel bends such as those at Cascade and Chinook.

In manufacturing the pipe used, Tenaris applied its cold end sizing process, a controlled deformation process that actually minimizes the ovality of the pipe ends. With this process, the mill can achieve +/- 1.2 mm from the agreed inside diameter of the pipe.

Tenaris integrated system of products and services ensures our customers’ most stringent needs are met.

Pipe protection for long run

Tenaris, working with international coating manufacturers, chose specific coatings designed to protect the pipe from corrosive and erosion effects.

Additionally, for the external anticorrosion protection of flowline carrier pipe and gas export lines, Tenaris used three-layer polyethylene/polypropylene coating system. Application consists of a layer of high-performance fusion bonded epoxy onto which a co-polymer adhesive layer is extruded, followed by layers of extruded polyethylene and polypropylene until the desired thickness is obtained.

For the Chinook flowlines Tenaris provide inner and outer pipe, for the pipe-in-pipe system, for the Cascade field the company provides flowlines with wet insulation system conventional three-layer anticorrosion system with additional layer of syntactic polypropylene, usable for the demanding high pressure and ultra deep water environment.

Tenaris
Mariano Armengol
Product Leader
marmengol@tenaris.com
Paolo Novelli
Product Manager
pnovelli@tenaris.com
V&M PROVIDES QUALITY SEAMLESS TUBULARS, PREMIUM CONNECTIONS FOR CASCADE AND CHINOOK

Vallourec & Mannesmann USA Corporation is proud to be chosen as a supplier of choice for Petrobras America’s Cascade and Chinook wells. V&M’s global network of mills located in the USA, France, Germany, and Brazil will provide casing and tubing with VAM® premium connections for this project.

V&M has a long-standing relationship with Petrobras and has been a key partner/supplier for Petrobras’ Brazilian deepwater and ultra-deepwater projects and operations through the years. By delivering quality products combined with logistical expertise, V&M has demonstrated a continued commitment to developing best-in-class performance for tubular solutions.

In the case of Cascade and Chinook, the majority of the casing has been produced in V&M’s Dusseldorf-Rath Works in Germany and V&M Star mill located in Youngstown, Ohio. V&M Star is producing OD sizes ranging from 5-in. to 10 ¾-in., while the Rath mills are capable of producing 7-in. to 24-in. The 4 ½-in. 13-Chrome tubing with VAM TOP connections is manufactured in Saint-Saulve, France. V&M’s hot-rolling manufacturing process ensures controlled wall thickness and ovality, minimum residual stresses, while V&M’s High Collapse proprietary grades offer properties exceeding the API ratings as required by the demanding Cascade and Chinook wells.

VAM premium threaded connections provide superior tension, compression, and bending ratings. Coupled, semi-flush, and flush VAM premium connections have been utilized. Each connection is manufactured with a metal-to-metal seal assuring gas-tightness even under the most severe combined loads as found in deepwater Gulf of Mexico wells.

The V&M and Premier Pipe LLC partnership provides exceptional supply chain management services to Petrobras. The two companies have combined their efforts to ensure continuous service from the mill to the rig, from pre-engineering, forecasting future tubular requirements, accessories manufacturing, inventory management, rig preparation of pipe and connections, to rig returns. Specially trained VAM Field Service representatives are on site to inspect all the connections prior to make-up. On the rig floor, each connections threads and seals are thoroughly examined, the running equipment is checked, handling procedures along with make-up torque parameters are monitored to ensure safe and efficient running of the string of pipe.

From pipe manufacturing and threading, to quality assurance and inspections, including field service, every step in the manufacturing process of V&M’s quality seamless tubes and VAM’s proprietary premium connections, is aimed at providing the most reliable equipment to the oil and gas industry.

This attention to quality, service, and the capability to provide virtually any size tubular required for an oil and gas development project, is why V&M is a global leader in quality tubular solutions.

V&M casing staged for transport to the Cascade and Chinook fields.

VAM® is a registered trademark of Vallourec Mannesmann Oil & Gas France

VALLOUREC & MANNESMANN USA CORPORATION
4424 West Sam Houston Parkway N., Suite 150
Houston, TX 77041
Tel: 713-479-3200
Fax: 713-479-3202
info@na.vallourec.com
Above and beyond the extra-large crane and pipelay vessels used for positioning and placing large-scale seafloor and subsea infrastructure for Phase 1 of the Cascade and Chinook project, Petrobras Americas also required the services of a very large marine service vessel to assist in installation of extra-critical subsea connections such as subsea trees, manifold components, umbilicals, flying leads and jumpers.

The vessel would have to have an expansive deck area, as well as a large boom crane, for such work, along with the on-site availability of multiple remotely operated vehicles (ROVs) to conduct subsea work and to observe and survey widely spaced well sites as well as the seafloor routes of the gathering system.

So, Petrobras lost no time in contracting with Veolia ES Industrial Services, whose special marine services division, based in Houston, provides the unique capabilities of its new multi-purpose construction support vessel, the MPSV Viking Poseidon, which is no less than the largest Ulstein X-BOW® vessel in the world.

The Viking Poseidon is intended to provide a wide range of offshore construction services, and is designed specifically for installation, inspection, maintenance and repair of submerged deepwater and ultra-deepwater installations, as well as for subsea survey, ROV and well intervention operations.

The Viking Poseidon is currently still working at Cascade and Chinook, engaging in subsea equipment fine-tuning and field integrity surveys.

The vessel did take a two-month leave of absence from the Petrobras project to aid in the killing of the deepwater Macondo Prospect’s wild well, helping to install critical oil recovery hardware and conducting sea-floor surveys around the wild well area.

**Advanced features**

Built in 2008 by Norwegian shipyard Ulstein Verft AS, the 6,804-tonne (7,500-short-ton) Viking Poseidon is 130m (427 ft) long and 25 m (82 ft) wide, with a side-protected cargo deck area of 1,470m² (15,823 sq. ft). It is capable of supporting 5,080-tonnes (5,600-short-tons) of deck cargo. The cargo deck also is fitted with an 8m x 8m (26-ft-square) flush-hatched moon pool. An EH 101-rated helideck is placed above the fore-ship superstructure.

The advanced features of the Viking Poseidon allow it to deploy heavier loads and operate further offshore at higher speeds while delivering excellent fuel efficiency, comfort and safety.

Among propulsion and dynamic positioning equipment, the vessel has diesel-electric main propulsion, along with three bow thrusters, two tunnel thrusters and one stern thruster, each equalized by below-deck roll reduction and anti-heeling tanks.

For subsea equipment handling, the Viking Poseidon is fitted out with an HMC 250-short-ton (227-tonne) hydraulic, active heave-compensated knuckle boom crane for heavier loads and a 15-short-ton (13.6-tonne), heave-compensated electro-hydraulic deck crane with folding boom for lighter loads.

Two Triton XLX 150-hp, ultra-deep ROVs, built by Perry Slingsby, are based on the vessel, along with their operators. The fully equipped XLX ROVs are rated for subsea services to a maximum depth of 4,000 m (13,124 ft).

The Marine Services division of Veolia Environmental Services - Special Services, Inc. (VES) offers a full range of offshore oil and gas and inland marine services.