Kikeh
Murphy sets new records for Malaysia’s first deepwater project
Contents

Discovery of Kikeh .......................... 2
Small Team, Big Results ...................... 5
Technology Transfer .......................... 7
FPSO Conversion .............................. 9
The SPAR Option ............................ 14
Innovative Flowlines System ................ 18
Drilling in Malaysian Deepwater ............ 22
Quality Assured ............................... 25
Expanding the Supply Base ................... 27
Company Profiles ............................. 28
“We are very pleased to have helped open up the deepwater business offshore Sabah, Malaysia through first exploration and now first oil production. The successful commissioning of Malaysia's first deepwater development marks a significant milestone for us and our partner Petronas Carigali. The Kikeh Field is a demonstration of our team's expertise and our dedication and commitment to the long term development of Malaysia's oil and gas resources.

With all that has been accomplished, I believe that we have demonstrated how global expertise infused with homegrown capabilities can work seamlessly to bring the country one step closer to becoming South East Asia's deepwater hub.”

— David Wood, President, Murphy Exploration & Production Company and Executive Vice President, Murphy Oil Corporation

“ We were delighted when we made Malaysia's first deepwater oil discovery in July 2002 and to have it come on stream within five years is a tremendous accomplishment. Despite being one of the most challenging deepwater developments, Kikeh has set exemplary records and standards in safety, execution and timing. We could not have achieved this if we didn’t set ourselves high standards from the onset of the project.

I would like to thank the entire Kikeh team for their hard work, dedication and professionalism on this project.”

— Roger W. Jenkins, Vice President, Sabah Operations, Murphy Sabah Oil Co Ltd
Malaysia and Murphy Oil’s future changed with the discovery of the Kikeh field in 2002. As Malaysia’s first deepwater project, Kikeh brought the country new opportunities for technology transfer and greater interest from the oil and gas industry looking for new hydrocarbon reserves. For Murphy Oil, Kikeh represented a project that eventually will double the company’s oil production.

On July 30, 2002, Murphy Sabah Oil Co Ltd, using Diamond Offshore’s semi-submersible drilling rig Ocean Baroness, made Malaysian history with the Kikeh No. 1 well. Until this time, Malaysians only knew “kikeh” as a small deepwater fish, but Murphy’s Kikeh development soon became known as a project that featured many industry innovations and one that would become Malaysia’s first deepwater project.

Located 65 nautical miles north of the eastern Malaysian state of Sabah, the development was discovered in Block K in water depth of 1,320 meters.

“It was our third deepwater well offshore Malaysia, and we knew early we had a major discovery on our hands — an exciting challenge for Murphy to grow in Asia,” said Roger W. Jenkins, Vice President for Sabah Operations of Murphy Sabah Oil. “Two more delineated wells confirmed the Kikeh prospect, estimated initially to be in excess of 400 million barrels of high quality crude oil.”

Planning and development
Jenkins immediately began building a team to manage one of the largest resource developments in Southeast Asia. The original three-man project team of 2002 eventually evolved into a core group of top professionals leading a staff of more than 85 people.

“For most of 2003, we planned and drilled four appraisal wells and carried out a well test for what is today an eight-reservoir large field,” Jenkins said. “We were quick to finish development plans, and by 2007 had completed and developed the field in five short years from discovery — a new industry benchmark.”

The project, with an estimated US$1.7 billion in investment, was sanctioned in April 2004, while partner Petronas Carigali Sdn Bhd and subsequently,

Steve Dechant, the Kikeh Project Facilities Manager helped craft the contracting strategy to put the project in the fast lane. "The strategy involved a small team approach that allows for timely decision making and clear accountability," says Dechant. The team was committed to selecting experienced and qualified contractors with a good industry track record. "Being Malaysia's first, this was key to our success at Kikeh."

The fundamentals behind our contracting strategy were:

- **Maximize the utilization of contractors' area of expertise** – the goal was to maintain the largest scopes possible that remained within the selected contractors' area of expertise.
- **Select only industry proven contractors** – the team was relying on the contractors to perform. Experience on the contractors part was essential.
- **Define functionality and allow contractors to be innovative** – functional specifications were used to maximize the use of contractors' unique systems and equipment.
- **Accept alternative approaches from the contractors** – alternatives were encouraged and accepted if the contractors approach met the functional requirements.
- **Utilize Lump Sum, EPCIC contracts where possible** – the...
team wanted to “lock in” to fixed prices with the busy outlook for the oil and gas industry in 2004 and beyond.

“Murphy awarded major contracts in December 2004 for the Floating Production, Storage and Offloading (FPSO) vessel, and the Dry Tree Unit (DTU),” said Jenkins. In early 2005, contracts for pipelines and the innovative Fluid Transfer Line (FTL) also were awarded. J.P. Kenny Mustang assisted with the Front End Engineering and Design (FEED) concept for developing the field in water depth of 1,320 meters. “It took us 10 months to complete the engineering and selected the final project concept,” Jenkins said.

“Everyone at Murphy was under enormous pressure when working on the documentation of the field development plan, and today the work, which was drawn some three years ago, was finished on schedule.”

**Interface management at work**
Managing a project of this magnitude is another challenge and an Interface Management group consisting of a Facilities Management team as well as Site Management teams, which were formed immediately, handled this. Cash flow and project payments also were handled by the project controls team, which managed milestone payment plans for each contract.

Work on the various contracts was carried out on a global scale — in the United States, Monaco, the Netherlands, Finland, Australia, Singapore, and in Kuala Lumpur as well as various other sites throughout Malaysia. “We had the project implemented in a multitude of places, which was a challenge. Through our Interface Management concept, we were able to manage the benchmarks of each contract,” said Jenkins.

“We also had a strategy that required each bidder to meet local content requirements outlined in their contract, and we followed up with experts overseeing the progress of each of them,” he said. “We did all this while maintaining a top level safety record and are proud to have delivered this project successfully.”

“Eventually we will have 13 producing wells on the Spar and three subsea wells,” said Bill Hughes, Kikeh’s Senior Production Manager. “We should be up to 120,000 bpd production by the end of 2008. We will also have six water injection wells on the Spar and 11 subsea wells, plus one gas injection well subsea until such time as the gas pipeline to Labuan (Petronas methanol plant) is completed in March or April 2008.”

“The happiest moments were when we awarded the contracts within a six-month time frame — the last quarter of 2004 and the first quarter of 2005, and the day we achieved first oil — Aug 17, 2007 just five short years from when the development began,” said Jenkins. “I am delighted we have successfully accomplished the development of this mega energy project in Malaysia.”
Small Team, Big Results

For the Kikeh project, Murphy Sabah Oil chose to utilize a “fit-for-purpose” Interface Management approach. The Facilities Team management consisted of a core group of people on the Project Management Team (PMT) based in Kuala Lumpur. That group included Facilities Manager Steve Dechant, Interface Manager Melih Oran, QA Manager Philip Howard and Installation Manager Doug Smiley.

Putting the team together
Each of Murphy’s EPCIC (Engineering, Procurement, Construction, Installation and Commissioning) Contract Teams, or Site Management Teams (SMT), varied in number of personnel and depth of coverage. Key to each SMT was the Contract Manager and Interface Engineer. Most teams also designated an Engineering Manager, who often was the same person as the Interface Engineer. Murphy’s Operations and Drilling and Completions Teams also interfaced with the Facilities’ PMT and SMT’s.

In total, approximately 85 people made up the Murphy PMT and SMT. Other oil and gas operators generally have project management teams twice that size. Because of the relatively small size of these teams it was essential that the key positions be filled with well-qualified and highly experienced engineers and managers.

“By industry standards, the Murphy PMT and SMTs were small sized team,” said Interface Manager Melih Oran. “As a general rule, our Facilities Team management approach was to trust the contractors to do what they are experts at doing and provide a fit-for-purpose facility in accordance with codes, rules and regulations and the contracts.”

Face to face communications
Interface Management requirements built into the EPCIC contract requirements included a Dedicated Interface Manager from each EPCIC and encouragement of direct communication between EPCICs. “Murphy was copied and kept in the loop, and helped facilitate, but generally we let the EPCICs request and exchange data as needed,” said Oran.

The wealth of deepwater knowledge, capability and technology for Kikeh came from all four corners of the world.
The EPCICs were also required to attend Quarterly Interface Meeting (QIM) held in Kuala Lumpur over two days. “Face-to-face communications proved to be invaluable,” said Oran.

Each EPCIC was encouraged to utilize their own interface management system, data sheets, format, numbering, etc. Oran noted that Murphy did not impose a unique “Murphy system” on them.

Ultimately, seven QIM sessions from April 2005 to August 2006 were held along with an Installation Campaign Readiness Review (ICRR) in late-January 2007, all in Kuala Lumpur.

Five main contracts
The interface program covered five main contracts, and the challenge was to keep information flowing between all parties involved in a timely fashion. “We had to coordinate with every one involved in the project including the contractors to keep to the schedule. A lot of energy was spent on ensuring smooth operations,” Oran said.

Brainstorming sessions were held among the managers, both at Murphy and with the contractors, he explained, noting that easily more than 100,000 management and engineering man-hours were spent on Interface Management.

All these hours were spent on daily communications, correspondences, weekly and bi-weekly project team meetings, weekly and monthly status reports, monthly multi-contractor Interface Teleconferences and the Quarterly Interface Meetings.

Staying on track
Murphy had stressed that all parties involved in the project hold party-to-party discussions. This resulted in every element of the development completed as per design, fitting into the functions of each component — for example the functioning and operation of the DTU, FPSO, FTL and TAD.

Interfaces between EPCICs could have posed substantial commercial and technical risk to Murphy. “If EPCIC ‘A’ hardware, controls, process, or installation activities did not mesh with Contractor ‘B’, then Murphy could have been exposed to cost and schedule delays to make it mesh as well as potential technical issues to make the interface work,” said Oran. “Also, when we were planning for installation, we tried to be aware of places where two groups would need to work at the same time so as to minimize simultaneous operations and any potential conflicts that might have resulted.”

“It was a learning process,” said Oran. “Sometimes we had to reel people back from focusing on the details, but we accomplished our goal to have first oil within five years of discovery.”

More than 100,000 management and engineering man-hours were spent on Interface Management, says Oran.
Malaysia has gained extensively from the implementation of the Kikeh deepwater project through technology transfer. Kikeh is one of the largest oil and gas projects to be undertaken in the country and that, too, on an accelerated pace in the award of five Engineering, Procurement, Construction, Installation and Commissioning (EPCIC) contracts.

Global project, local capabilities

The Malaysian national oil corporation, Petronas Nasional Berhad (Petronas), had set up a special tender committee for the project, the first deepwater development that has introduced technologies for building Spars, and other components of deepwater oil exploration and production to Malaysia, according to Tengku Saifuzzaman Tengku Ahmad Shahruddin, Development Manager at Murphy Sabah Oil Co. Ltd.

“Technology transfer has taken place in every aspect of the high-end equipment, plants and materials that are being used at Kikeh,” he said.

The FPSO, Spar, FTL, and subsea manifolds were fabricated in Malaysia, while a portion of the subsea trees was assembled in the country.

Government support

“Murphy and Malaysia have demonstrated that we can handle projects of this magnitude,” he stressed. “Petronas’ collaboration has been unwavering in terms of project support and procurement, especially in facilitating tender approvals.”

Malaysian governmental agencies lent full support during the importation of equipment and material, ensuring a smooth flow of items for the mega project, Tengku Saifuzzaman noted. Most of the components were brought into the country within one year, starting from the second quarter of 2005.

The 2005 construction period was a big challenge, he added, amongst which:

• Getting the equipment and materials into the country on time
• Interfacing with the EPCIC contractors as well as their subcontractors and vendors
• Maintaining project schedule
Murphy was very specific in selecting the right equipment and material, with its project team reviewing every aspect of the items.

“We had a design competition and invited all four manufacturers of the DTU. But we decided on the Spar design as the most economically suitable option for producing oil from the field,” he said.

The Kikeh deepwater field development is a major landmark project for the Malaysian upstream industry, as it marks the country’s successful foray into deepwater production of hydrocarbons, thereby establishing the credentials necessary for the country to realize its aspirations of becoming the region’s deepwater hub, stressed Alfian Mohamad, Murphy’s Site Engineer for the Kikeh project based at MMHE’s Pasir Gudang yard in southern Peninsular Malaysia.

Technology Transfer

Kikeh has seen technology transfer taking place in every aspect of the facilities and services being used.

- Ensuring the availability of manpower resources
- Maintaining strict safety standards

Local Content

Total Man-hours Worked = 11,611,263

- Subsea: 111,451
- PL&R: 145,496
- FTL: 324,480
- DTU 3,662,030
- FPSO 7,367,806
In areas of the world where pipeline infrastructure has not yet been developed, Floating, Production, Storage and Offloading (FPSO) vessels are an integral part of offshore projects. Murphy Oil’s Kikeh development is similarly using a Very Large Crude Carrier (VLCC) for its production, processing, storage and offloading of crude oil and managing natural gas output.

Malaysia International Shipping Corp Bhd (MISC) and Single Buoy Mooring (SBM), the global FPSO operator, joined forces to provide one of the best production options for Kikeh, and converted the 1974-build Atlas VLCC for FPSO Kikeh.

FPSO Kikeh takes shape
Responding to Murphy Oil’s call for a world-class FPSO, MISC and SBM formed the joint venture, Malaysia Deepwater Floating Terminal Sdn Bhd (MDFT), which acquired the VLCC formerly owned by the Stena Group and converted it into a Class A1 FPSO to standards set by ABS Group.

Atlas’ hull is made of thick mild steel with 35 mm bottom plates, which provide ideal fatigue characteristics for a 20-year offshore field life. “As a VLCC trading vessel it was well maintained, and, as such, a significant amount of the vessel systems and equipment have been retained and refurbished to support the new operation,” said Barry Courtney, Murphy’s FPSO Manager.

A Kikeh project-specific SafeHull A analysis was performed on the Atlas, as were extensive inspections. Indeed, in addition to superior fatigue resistance, the thick plates provide larger corrosion margins.

The Stena series is well known by SBM, which has been operating a Stena Concordia class tanker as an FSO for more than seven years and owns two other Concordia class sister-ships for conversion to FPSO in present market. The Atlas design is typical of the pre-

The FPSO is the central processing facility for Kikeh measuring 367m in length, breadth of 55m and weighs 273,000 tons
Marpol single hull VLCCs built in the mid-1970s.

**Production onboard**

MDFT signed the letter of intent with Murphy Oil in December 2004 and immediately began engineering and design for now-renamed FPSO Kikeh to accommodate the field life span of 20 years. "Its topside facilities are designed to handle and store 120,000 barrels a day of crude oil, 150 million standard cubic feet per day of natural gas output and 260,000 barrels a day of water injection," said Courtney.

The FPSO has plants for compression and conditioning of the associated gas for gas injection and future export of gas. The target is to have zero gas flaring on the FPSO. Treated gas from the produced hydrocarbon is used to fuel the main boilers and the topsides gas turbine generators on the FPSO deck.

Space has been reserved on the FPSO Kikeh to add another equipment module in case of enhanced production or future tie-in from related field development. Utilities such as power generation, heating medium, cooling medium, and instrument air will either come with this new module or that the available utilities on the FPSO will accommodate the incremental demand.

The FPSO was converted at the Malaysia Marine and Heavy Engi-
neering (MMHE) shipyard at Pasir Gudang, located on the southern tip of Peninsular Malaysia near Johor Bahru. Equipment and material procurement were administered to Petronas guidelines and the FPSO’s design specifications included SBM Corporate Engineering Standards.

**Turret technology**

The external turret mooring system on FPSO Kikeh consists of an extension from the vessel’s bow called the rigid-arm, which supports a turntable, a gantry, a slewing bearing, two manifold decks and a chain-table. Anchor lines are attached to the chain-table by means of unijoints. The bearing allows the turntable to freely weathervane around the anchoring system so that the vessel can take up the position of least resistance to the prevailing weather at all times.

Hydrocarbons are transferred to the FPSO turret from subsea wellheads via flexible risers, and from the Dry Tree Unit (DTU) via production flowlines supported by the Fluid Transfer Line (FTL). The three-phase production fluid then enters the turret manifolding system where it is directed into production manifolds, one high-pressure production, one low-pressure production and one test manifold. The crude passes through dedicated torodial swivels and onto the FPSO’s process system.

High-pressure gas and water pass in the reverse direction from the FPSO process system through the turret via similar means for injection into the field to provide enhanced means of oil recovery. Provision for future handling of a subsea tie-back, as well as future processed oil and gas has been allowed in the turret. Electro/hydraulic umbilicals carry power, instrumentation signals, and utility fluids to the subsea manifolds and the DTU.

The turret is designed to allow mooring legs and risers hook-up on site with riser lifting and chain
The first turret-moored FPSO used in conjunction with a Spar

tensioning being carried out by a chain pulling electro/hydraulic winch which is permanently located on the turret and energized with temporary jumpers from the FPSO.

The horizontal position of the turret structure relative to the vessel is determined by the so-called extreme “overrun” condition. This is the condition where the vessel moves ahead of its center position, so that the anchor lines, which are below the keel of the vessel, are tensioned. The usual design case for the overrun condition is the tail end of a storm, when the wind speed drops, but waves are still strong.

The bow extension, the distance between the turret center line and the vessel fore perpendicular, is sufficient to maintain a positive clearance between the hull of the vessel and the anchor leg passing under it in an all overrun cases. As part of the conversion work, the tanker bulb was cut to optimize the bow extension, while accommodating the rigid-arm structure retrofit.

Pitch and heave

In vertical position, the turret is positioned such that when the vessel is at its fully loaded draft, the turntable main deck remains clear from the wave crests in severe weather conditions. The required air gap is
defined taking also into account vessel motions — pitch and heave.

The turret fixed part, geo-stationary, forms the non-weather-vaning side of the vessel mooring. It includes the chain table at the lower rim, and is suspended from the main slewing roller bearing mounted on the upper side of the turret turntable. The fixed part houses the riser termination and the piping between the riser and the swivel entry. The fixed part structure transfers the mooring loads from the anchor legs to the extension structure, rigid arm, via the turntable.

**Upper and lower decks**

The manifold decks are supported from the upper side of the slewing bearing. It includes the main slewing roller bearing and the riser interface with turret is designed on the basis of flexible risers, each equipped with a sliding bend stiffener. The riser interface with turret is based on a series of I-tubes of typically two to three meters in length.

The base of each I-tube is designed with a support flange and bolt circle to interface with the flexible riser bend-stiffener. The purpose of the bend-stiffener is to maintain flexible pipe curvature at the turret interface within allowable limits.

The anchor legs are arranged in a pattern of three bundles of three equi-spaced legs, each bundle 120 degrees apart to each other. The mooring legs are configured with an angle of five degrees between each line within a bundle.

**20-year field life**

All operations on the DTU/Spar, which is rated as an unmanned platform, are being handled from the FPSO.

The vessel has accommodation for 118 people with lifeboats and rescue boats as a full part of the safety and rescue operations. It is also equipped with a helideck designed for a Sikorsky S61N and S92A helicopters.

“The design premise was for FPSO Kikeh to remain on site during the 20-year field life without the need to dry-dock, providing many years of service for this key Malaysian deepwater development,” said Courtney.
The SPAR Option

The Kikeh Spar project was a new engineering challenge for Malaysia and the team of international engineers tasked to design and build the Spar. A Dry Tree Unit (DTU) on a cylindrical floater was deemed the best economical and technological option for oil and gas production from the deepwater Kikeh field.

Early planning and about 15 parallel studies were carried out for Malaysia’s first Spar project as soon as Murphy Sabah Oil selected the economical Spar option for the Kikeh project instead of other deepwater choices, including a tension leg platform (TLP).

“This was a fast track project for which we did various studies parallel to design work,” said David Sims, Murphy’s topside client representative. “In addition to the studies, we designed models modified to suit Malaysian waters,” he adds.

The Malaysia Marine & Heavy Engineering Sdn Bhd (MMHE) shipyard based in Pasir Gudang, Johor, on the southernmost tip of peninsular Malaysia and international engineering group, Technip, took on the challenge of building the country’s first Spar.

Work began in February 2005

“The Spar is easier to move over the drilling areas, especially the deepwater basins and it may actually help speed up the drilling,” Sims said. However, it still was a challenge to work on the Spar. “We began with the basic piping and instrument drawings, and had to consider various elements including the well condition and temperatures.”

Considerable attention was paid on how to manage weight on the deck. Though the Spar is moored on site, it is subject to movement based on the sea waves and wind flow.

Geotechnical study on the seabed covered the current flow and wind direction among other aspects, and environmental, safety and hazardous studies all helped in the design of the Spar.

“We even did a study on heat dispersion for the two flares on the Spar as wind directions are very impor-
tant, given the highly sensitive materials on the deck,” said Sims.

Other materials on the Spar topside include corrosion inhibitors and demulsifiers. Engine exhaust study was another major contributor to the deck planning for the Spar, which houses a large quantity of methanol to be used for well injection to help with the oil flow from the well-depth as well as through the 1,320 meters of water depth. “Oil flow from such deep sea environments tend to freeze,” said Sims.

Continuous studies and reviews
A highly crucial study — the Reliability, Availability and Maintainability (RAM) study — helped select all the main components for the Spar deck. Sims singles out one example of the generators. “We wanted to ensure we have generators that were reliable, available on schedule and were maintenance friendly.”

The Spar’s topside design was completed in about six months at Technip office in Kuala Lumpur.

The Murphy team continuously reviewed the designs and studies. The challenge was to build an unmanned Spar-based production platform. Once the production/development well drilling program is completed, the unmanned DTU platform would be operated from the FPSO Kikeh, located 1.6 km away.

A 48-inch diameter Fluid Transfer Line (FTL), which is a first of its kind of floated pipeline, links the FPSO Op-

The Spar is easier to move over the drilling areas especially in deepwater basins

The Spar hull was loaded onto heavy transport vessel, The Mighty Servant 1, and sailed to Kikeh site on September 26, 2006
erations Room with the DTU. The heavily coated FTL has three 10-inch lines, one 8-inch line and umbilicals. It transmits operational signals and power supplies for the plants on the Spar.

Handling the Spar

Three cameras located in the FPSO Operations Room monitor operations at the DTU and the surrounding area of the Spar. “These will be the eyes,” Sims said.

The Kikeh Spar topside is designed for 25 wells, but the initial field production will come through 14 wells, including three water injection wells through a manifold system.

A multi-phase flow meter will be used to monitor and manage the flow of oil to the FPSO production/processing system. “We have designed the system to pump ‘dry oil’ or the processed oil from the FPSO to DTU,” said Sims. This oil will be pumped into wells to re-start wells or if any one becomes hydrated.

“There are no plans to shut any well once it starts producing, but we have taken precautions as it will be necessary to shut wells in case of emergencies, such as fires or blow-outs,” Sims explained. It is called the Emergency Shut Down (ESD) system.

Safety first

Other main equipment on the Spar deck includes fire-fighting equipment, water pumps to fight fire, almost all of which are housed in the Mechanical and Electrical Building (MEB).

The Spar’s topside will also have diesel pumps for supplying fuel to the two cranes and the 1,000-kilowatt generators.

“We have also placed two 22-man lifeboats and two 25-man rafts on the deck,” he adds.

All these are safety measures for drilling crew and crew that would be sent on the deck during well work-over programmes and wire logging of wells. On average a six-man team is expected to be on the Spar/DTU deck during maintenance work.

Technip Finland, which has designed some 15 hulls for Spars, designed the Kikeh Spar hull while MMHE fabricated it at the Pasir Gudang yard.

“Work on the hull started during the rainy season of 2005 but fabrication process was continued around the clock,” says Rahim Mamat, Murphy’s Site Engineer with 25 years of field experience and in charge of the Project Control and Scheduling.

“It was a learning curve for the first tank, and it took us 14 months to fabricate the hull, which was also a first-time project at MMHE and in Malaysia,” he adds.

Twenty engineers from Technip Finland along with the Murphy and MMHE teams met the challenge of completing the largest section of the Spar, weighing some 13,000 tonnes.
“We also worked on the topside concurrently, including the process and instrument drawings,” he said.

The Spar’s hull is designed to bear the impact of a collision with a ship, though such incidents are unlikely.

The lower part of the four-section hull comprises of hard tanks for ballast, but ballast would not be used as the hull is designed to float. Heavy slurry will be stored for balancing the Spar. The two-heave plates in the Truss Section and soft tank balances the Spar.

The semi-tender assist drilling (TAD) rig is another component of the project. It was important to design the Spar to accommodate the mooring point of the TAD. 

The topside being prepared for transfer onto the Spar hull via a float-over technique
One of the unique features of the Kikeh project was the industry introduction of a Fluid Transfer Line system between the Spar and the FPSO.

Single Buoy Mooring (SBM) developed this concept, also known as the Gravity Actuated Pipe (GAP) system, for the near-surface transfer of hydrocarbon fluids between two floaters, such as a Spar and FPSO, on deepwater oil fields. The Kikeh Spar and FPSO are located 1,600 meters from each other.

“There were several challenges with using seabed flowlines,” said Geoff Stone, Kikeh Project FTL Manager. “The FTL was built as an alternative solution to these hurdles.”

The Kikeh flowline challenges included:
- Flow assurance due to low seawater temperatures
- The high discharge pressure to overcome the pressure drops induced by much longer flowlines length
- Seabed congestion

The EPCIC contract for the provision of the Kikeh FTL system was awarded to SBM in April 2005 with a targeted completion date of September 2007.

**Continuous steel pipe suspended between floaters**

The Kikeh FTL system bundles the production flowlines and power/control umbilical around a carrier terminated with two towheads, the latter being suspended from the Spar and FPSO by tether chains.

“The carrier-pipe is a continuous steel pipe,” said Stone. Its diameter is 1.2m increased to 2.3m at its extremities with internal bulkheads for ensuring its structural integrity in case of damage (buckling under external pressure). “The diameter of the carrier-pipe is determined so that its buoyancy keeps the bundle within the prescribed high and low water depth limitations when it is subjected to the density variations of the conveyed fluids. The submerged weight of the bundle is adjusted by trimming chains installed along the bundle length,” he added.

Kikeh's FTL is the first in the world that uses gravity actuated pipe (GAP) technology.
The towheads, located at each carrier extremity, support the fluid and mechanical connections of the bundle to the Spar and FPSO. Specifically:

- Flexible steel jumpers and intermediate steel pipe spools connect four 10 diameter flow-lines, which include two high pressure and one low-pressure product lines, as well as one water injection line, to the Spar and FPSO. The towhead includes also two heavy clump weight chains for stability.

- On the Spar side a taut twin tether chains arrangement connects the towhead to the Spar at 60 m water depth (one of the chain is redundant).
- On the FPSO side a catenary twin tether chains arrangement connects the towhead to the FPSO turret (one of the chains is redundant). The weight of the chains catenary is increased by the incorporation of steel weights clamped to them. Also, the additional weight...
of the arrangement is compensated by an overhead buoyancy tank which provides added stability,
• The umbilical, which is connected between the two topside facilities via the FTL system in a continuous length, provides high voltage electric power to the Spar and enables instrumentation data exchange via optical fibers.

Fabrication and launching
SBM fabricated the FTL on a temporary purpose-developed site near Bintulu, Sarawak. This site consisted of a reclaimed strip of land, 1,600m × 100m, perpendicular to the coastline, on which a railway track was installed to run the bogies used to support the system during launching to sea.

The carrier 20m sections were prefabricated using a high quality fabrication shop process and assembled on the launching bogies into a continuous system 1,300 m long. Semi-automatic welding and automated ultrasonic inspection (AUT) were of the highest quality. The towheads’ caissons and wing tanks were prefabricated at Johor Baru and Bintulu and assembled at the ends of the carrier.

“The flowlines were fabricated using quality pipeline fabrication methods on either side of the launching track and later lifted into the articulated supports clamped to the carrier-pipe,” said Stone. The jumpers/umbilical termination supports were installed and the connecting rigid pipe spools (to be installed offshore) were prefabricated and field tested using dummy jumper termination. All flowlines and spools were hydro-tested on site.

Tow To Field and Installation
“The FTL launching began on May 8, 2007 with the
arrival on site on the main installation vessel, SBM's Normand Installer and numerous assistance tugs and patrol boats," said Stone.

The FTL system was towed on the sea surface along a pre-defined route using the Normand Installer. Upon arrival at the Kikeh field, each of the two chains of the FTL was connected to the Spar and then the FPSO. This was followed by installation of the flexible jumpers and the control umbilical. This phase of the installation work was completed on June 10, 2007.

In order to complete the FTL system installation and to allow its commissioning, subsea divers from SBM's diving subcontractor Offshore Subsea Works installed connecting steel rigid spools at the Spar and FPSO locations at water depths of between 65m and 190m. They completed the work by August 12.
Drilling in Malaysian Deepwater

The Kikeh field was discovered using Diamond Offshore’s Ocean Baroness. The Baroness was then used for two appraisal wells in the field before being released from the site in late 2002. The two rigs used for development work on the project were Diamond’s Ocean Rover, a semi-submersible, and Sea-Drill’s West Setia, a semi-tender assist drilling rig. The average development well depth ranged from 3,000 to 5,000 meters in 1,320 meters water depth.

The variable sand quality, number of reservoirs and shallow hazards make the project unique, according to Michael McFadyen, Senior Drilling Manager at Murphy Sabah Oil Co Ltd.

Managing logistics

“One of the biggest challenges on the drilling and completions side was managing logistics in an area where we were the first to develop in deepwater,” said McFadyen. “This involved keeping the rig operation supplied with equipment, materials and specialists to continue uninterrupted operations to avoid downtime and meet the schedule.”

The batch-set operation for the structural and surface casings was the largest of its kind for Murphy and Diamond Offshore, setting 23 wellheads in 63 days. More than a million sacks of barite were transported to the shore-base facility, mixed into liquid mud and consumed offshore on the Rover. These large volumes and quantities of materials required a major upgrade of the shore-base facility before the project start.

Additionally, the supply base had a very small number of berths available for the larger deepwater vessels, requiring berth sharing with other operators. “The successful Kikeh batch set operation was very intense and required a strong team effort, solid planning, and clear communication,” said McFadyen.

Ocean Rover and West Setia

The West Setia will drill and complete a total of 18 wells from the Kikeh Spar while the Ocean Rover semi-submersible will be responsible for the 17 sub sea wells. “The West Setia represents another first for the industry by utilizing a semi tender assist drilling rig on a Spar host facility,” said McFadyen. “The key challenge to overcome on this was to make the installation and rig-up during the monsoon season.”

The Kikeh development drilling and completion cost is in the $15 million range for each Spar well and $25 million per sub-sea well.

The total drilling completion budget was in excess of $800 million, says McFadyen, who oversaw well engineering, cost estimation, well design and well delivery for the project. At first oil, there were 11 subsea and five Spar wells drilled on the development.

Typical casing designs for a Kikeh subsea well is 36”, 20”, 13-5/8” and 9-5/8” casings. The Spar wells were similar but used 16” instead of 20” to slim down the
At first oil, five Spar and 11 sub-sea wells were drilled on the development.

West Setia, a semi-tender assist drilling rig, will drill and complete 18 wells from the Kikeh Spar.
The West Setia’s 16-3/4” surface blow-out prevention stack being rigged up prior to DTU drilling operations.

riser and reduce loads on the Spar.

The producers were completed cased and perforated or open hole with Expandable Sand Screen dependant on the reservoir properties. The injectors were cased and perforated or expandable sand screen in casing.

“A ‘lessons learned’ data-base, pre-planning and field involvement all helped to foster teamwork and success,” said McFadyen. “The average well is now being drilled in approximately 1.5 days / 300meters from spud to TD.” The best completion time to date was on the Rover at 11 days through well clean up. The team pushes for continuous improvement and incorporates lessons learned on previous operations in current planning.

Murphy has the experience of drilling in Malaysian deepwater, having drilled 30 wells since 2002 in Blocks K, L, P & H, including the July 2002 Kikeh discovery. The oil and gas company also has the...
Quality Assured

Quality Assurance and Quality Control management is a mammoth task for a project of Kikeh’s scale. Industry expert Philip Howard spearheaded Murphy’s efforts which ensured that every piece and item used in the development and operation of Kikeh field for 20 years was tested, audited and classified to international standards — ISO 9000, ASME, API, AWS, DNV and ABS.

Cost-conscious Murphy conducted Quality Assurance (QA) at a much reduced cost of similar projects of this magnitude by relying on the contractors to perform the Quality Control (QC) function.

“To achieve this, we had at least one dedicated QA expert assigned per Engineering, Procurement, Construction, Installation and Commissioning (EPCIC) contract performing Quality Assurance oversight of the contractor’s activities and sites,” said Howard, the QA/QC Manager at Murphy Sabah Oil Co Ltd.

Periodic audits

“Periodic audits were also carried out with independent third parties to ensure we have the best quality products in place for the field which is designed to produce for 20 years without significant maintenance shutdown,” according to Howard.

Specialists and experts were taken on to assist in auditing the contractor and its various vendors’ work practices and sites where the work was being carried out as well as the finished product, in the case of safety or production critical equipment. “We felt that was the most suitable way of handling Quality Assurance, without having to take on a lot of staff,” he explained.
Due diligence in specific areas, including HSE, fatigue, structural process analysis etc., also was carried out as part of the QA effort utilizing specialists via auditing processes.

“One other aspect of the Quality Assurance role was to monitor and verify the required certification of various segments of the project,” he said.

Constant monitoring was carried out on certain critical aspects of the assets/facilities, gas compressors, riser systems, power generation, control/safety systems, and cargo system as well as the contractors’ ability to handle the assigned project. A failure of any of such systems would be potentially dangerous and would cause loss of production as well as potentially assets and lives, Howard pointed out.

Welding was one of the most critical issues in the process of putting together the Fluid Transfer Line due to the extremely minute welding defect sizes allowable to achieve the 20-year life of the Kikeh field.

“The contractors stepped up to the plate and provided the necessary hands on Quality Control functions to provide a quality product,” Howard said.
Expanding the Supply Base

The Kikeh field has a dedicated supply base to ensure a smooth flow of supplies for producing up to 120,000 b/d of crude oil and 150 million standard cu ft per day of natural gas for the next 20 years. Murphy’s Logistics Manager Mark Adams led the base development, which is located at the Asian Supply Base on Labuan island, off Sabah. Other oil and gas companies have operations located in other parts of the base.

Gearing for fast growth
Murphy invested $6.5 million on upgrading its portion of the 55,000 sq acre base, where its staff of 26 runs the daily operation. The base upgrading was accelerated with work started in September 2005 and completed by April 2006 as installation work began in the field.

Located some 120 km from Kikeh field, the base is geared for the fast-paced development, especially the installation and initial three years of production. “After three years, the focus shifts totally to support for the production function,” said Adams.

In addition to the building of a new pipe yard, the existing jetty and pipe yard have also been upgraded, noted Adams. Five offshore support service boats, four anchor handling tug and supply boats, one crew boat, and two helicopters ferried supplies such as OCTG tubular goods, drilling equipment and people to work on the drilling rigs as well as the FPSO and the DTU.

Sikorsky S-76 C+ helicopters lend aviation support to the field’s structures. The hangar was especially upgraded for the two helicopters.

Peak activity
The challenge was at the peak of activity when the base contained huge stocks and inventories, including 6,000 tonnes of conductor/casing, 40,000 tonnes of dry bulks, 34,000 tonnes of liquid mud, and 6,500 tonnes of fuel and water.

The liquid mud plant at the base was upgraded to 1,000 barrels of oil-based mud capacity and the addition of 10,000 barrels of water-based mud new capacity as well as 8,500 barrels of brine capacity.

The base has supported the transportation and installation of 13,000 tonnes of the Spar hull, and 4,500 tonnes deck floatover during the development phase while the production wells were being drilled.

“The goal was to have suitable resources available to support the peak activity as the project moves into a mature operating environment,” says Adams.