Abstract

The Jubilee Field is a deepwater development located approximately 60 km offshore Ghana that was executed over 3.5 years between discovery and first oil production. Meeting this aggressive schedule required the fast-track execution of the turret-moored FPSO, named Kwame Nkrumah, as the FPSO was consistently on the project’s critical path schedule. A key to successful delivery of the FPSO on the fast-track schedule was establishing a strategy and adhering to the strategy even under multiple challenges. The details of the fast-track strategy, the challenges imposed, and the actual performance of the FPSO execution team in delivering the FPSO safely to location will be covered in this paper. This work also highlights the importance of building a multi-discipline team driven by clear, well-understood goals, creating a structure suited for execution, and of selecting the right Contractors for the project and building strong relationships with them.

Although fast tracking major O&G development projects is often a stated objective for many projects, few achieve the performance achieved on Jubilee. This work illustrates the establishment of a solid strategy and successful execution of that strategy to deliver an FPSO to the site in 22 months from award of contract. Despite the effort put in place to meet an aggressive schedule, the project team still encountered some significant challenges during the execution of the FPSO design, engineering, and construction. The key to successfully resolving these challenges was the team’s ability to stay true to the execution strategy as well as develop a response plan to meet the challenges and implement it successfully and safely.

Introduction

The Jubilee Field was discovered in June 2007 in the Gulf of Guinea, approximately 60 km offshore Western Ghana. It is a very large, light, sweet oil accumulation in 1200-1500m of water. The Jubilee Partners, along with Ghana National Petroleum Corporation (GNPC) decided in January 2008 to develop the field using a phased approach, after just one appraisal well. Kosmos Energy was appointed Technical Operator to lead an Integrated Project Team (IPT) in executing the development project and Tullow Oil (Ghana) was appointed Unit Operator to execute in-country activities, deliver wells, and operate and manage the field in the future. A third major partner, Anadarko, provided numerous key project personnel to the IPT. The IPT developed a plan to target just under 300 million barrels in Phase 1 with a 17-well subsea well system and 120,000 bopd FPSO. Phase 1 was approved by Partners in August 2008, and First Oil was achieved in November 2010, within the aggressive goal set by GNPC and the Jubilee Partners.

Keys to FPSO Fast Track Development

An aggressive, schedule-driven Jubilee Project Development execution required the fast-track delivery of the turret-moored FPSO, named Kwame Nkrumah, consistently placing the engineering, procurement, fabrication and transportation of the FPSO on the project’s critical path schedule. Key to the successful delivery of the FPSO on such a compressed timetable was the establishment of an early overall strategy which included,
• use of a functional design basis;
• use of proven, off-the-shelf technologies and designs;
• teaming with a robust FPSO provider with an established, well-proven supply chain;
• use of industry-accepted engineering and quality standards;
• project management with a small, experienced, empowered, integrated project team
• focus on use of the 80/20 rule for making decisions; and
• alignment with Project Management on key overall project drivers and priorities.

The execution success came from adhering to the strategy even under multiple challenges. The details of the fast-track strategy, the challenges imposed, and the actual performance of the FPSO execution team in delivering the FPSO safely to location will be covered in more detail through the remainder of this paper.

Step One: Early Strategy Development

The first step in the successful delivery of the Jubilee FPSO was the establishment of a clear strategy to guide all planning and execution activities, and alignment of the selected strategy with key overall project drivers. This process began early with the decision to utilize an approach based on functional specifications, a clearly established preference for use of well-proven previously implemented solutions, the need for a mature FPSO provider with an established supply chain, and the implementation of an aggressive tendering schedule. These decisions were made in alignment with management's expectations during the early weeks of the project execution in February 2008, as the IPT realized this was the only way to meet the demanding project schedule.

The functional specifications were developed very early in the conceptual stage, which the team executed over a six week period during the first few months of the project. This conceptual development process included an initial survey of the community of FPSO providers through an inquiry letter, pre-qualification of those providers deemed to be able to meet the Jubilee Project requirements in terms of contractor capability, experience, backlog, and proven ability to meet schedule. The pre-qualification process yielded four suitable, well-established contractors chosen to bid on the FPSO. Using input from the overall team, and with the assistance of Mustang Engineering, and Crondall Energy (both acting in role as Project Owners' Engineer), and the FPSO Contractors themselves, the IPT developed the functional specifications.

The functional specifications mainly identified the required capacities, details and expectations for the inlet and outlet streams and performance requirements of the FPSO but did not prescriptively dictate how to achieve the required metrics, as shown in the example in Table 1. The tender package specifically instructed the FPSO contractors to demonstrate how they would utilize previously engineered and/or built systems, with well established supply chains, to meet the functional specifications. This approach is believed to have provided improved schedule and cost surety due to contractor familiarity with its proposed systems and the benefits of lessons learned from prior projects that utilized these same solutions. In addition, the focus on use of previously engineered/built systems allowed the team to fast-track the bidding process, with a less in-depth evaluation approach to the technical details. The tender process was executed over a six week period from 30 April, 2008 to 10 June, 2008, followed by an intensive evaluation process which resulted in the award of a Letter of Intent to the successful contractor MODEC (FPSO Contractor) on 24 July, 2008. The significant milestones in the Jubilee FPSO development process are shown in the chart in Table 2.

As part of the fast-track delivery strategy, the initial Letter of Intent included commitments to purchase key long-lead equipment related to the turret, power generation, water injection and gas compression packages. The identification and procurement strategy for these critical systems was done in conjunction with FPSO contractor, who provided the specifications, placed the order, and jointly with the IPT established acceptable commercial terms to ensure timely delivery of the necessary equipment. Cancellation fee schedules were used to provide flexibility and protection to all parties during this early pre-contract phase of the project. The FPSO Contractor further reduced project schedule risk by pre-purchasing and committing to a Very Large Crude Carrier (VLCC) hull suitable for conversion.
Step Two: Stay True to the Strategy and Limit Changes

Having chosen and secured a contractor to supply a FPSO that demonstrated a clear approach incorporating previously engineered and proven systems, the next key to success lay in assisting and supporting this contractor to execute the required work safely in the most expeditious manner. This included working closely with the FPSO Contractor to quickly achieve a suitable detailed design based on existing sub-systems, implementation of a desirable contracting strategy, and instituting limits and controls to significant changes in the design of the chosen systems due to preferential engineering.

A key factor to the success of this effort was the integration of experienced, multi-cultural, creative individuals into a joint MODEC/IPT delivery team. This team worked together to overcome the demands of an accelerated delivery schedule for engineering, procurement, fabrication, integration and pre-commissioning work scopes associated with the FPSO. Much credit is given to the FPSO Contractor’s leadership and acceptance of an integrated team approach to managing an effort that, traditionally, has fallen to the sole responsibility of the FPSO provider with a staged review process by the Operator. The continuous interaction in the joint team was instrumental in meeting the aggressive timelines needed for a successful delivery.

MODEC along with its subcontractors quickly integrated previously engineered/constructed modules into a comprehensive topsides design meeting the agreed functional specifications. The key to ensuring fast-track scheduling was to minimize changes to the systems while assuring that the systems delivered the long-term safe performance required by the Unit Operations team. This balance is always a difficult one to maintain but was reinforced by a partnership that stressed the need to get a safe production system on the field producing oil as soon as possible even if the system was not optimized in terms of performance or preference. It also involved bringing Operations support into the IPT very early in the design stage in order to incorporate as many operational aspects as possible into the base design prior to procurement and fabrication.
The FPSO Contractor quickly delivered on its proposed contracting strategy, using a Far-East subcontractor-based supply chain strategy mostly based out of Singapore and Malaysia. Using a group of well-established, proven primary subcontractors within the same geographical area allowed both FPSO Contractor and the IPT site team to regularly monitor quality and progress of the modules fabrication and hull conversion work scopes and ensure a well-planned integration process. During the 18-month module fabrication, hull conversion and integration period on the FPSO in Singapore, key members of the IPT were temporarily relocated there or traveled frequently there to ensure that the schedule was maintained.

**Step Three: Make Decisions Quickly**

With FPSO work ongoing in Singapore and other Far-east locations, it was imperative that the IPT was able to make decisions in a timely fashion so as not to impede the project activities and insure that they continued at a safe, accelerated pace. Decisions were made quickly by placing empowered team personnel in strategically advantageous locations, integrated with the FPSO provider teams, providing regular and effective communication throughout the team, and regularly making decisions using the 80/20 rule with priority on safety, operability and schedule. It was also imperative for the delivery team to stay well aligned with the Jubilee Leadership Team’s (JLT) overall priorities and key drivers throughout this process.

Since IPT personnel were relocated to the location of key fabrication and integration activities remote from the team’s home base in the United States, these representatives were empowered to make certain decisions with limited input. Each member of the team was made fully aware of the details of the schedule—both for their areas of responsibility as well as other parts of the project that interface with their areas. In addition, regular meetings were held in Singapore to bring the entire team up to date on various project activities and allow them to receive and provide feedback on the development of the FPSO systems. Attendees at these meetings included members of the Installation, Hook-Up, and Commissioning (IHUC) teams as well as Operations Teams, Project Services, and General Project Management. Eventually, IHUC and additional Operations personnel also joined the site team in Singapore to actively work on the FPSO and ensure a smooth and safe transition to Operations.

Because of the speed with which the project was executed, there were numerous occasions where decisions had to be made without the full benefit of having 100 percent of the back-up information. In these cases, the team would use the commonly-referenced “80/20 Rule” to make the decision without complete information. These decisions were generally made as a team and accompanied by a simple but effective risk assessment, identifying and evaluating what risk or downsides were associated with this decision and the implications if the wrong decision was made. If the site team was comfortable the level and consequences of risk identified were manageable, and within their directive, then the decision was made. Otherwise specific additional information was identified and sought, or in some cases the decision was lifted higher to the JLT.

This need for very timely decision capabilities required that an experienced and knowledgeable group of people were brought together into a high-functioning team, both from the FPSO Provider and the Operator. This functionally integrated approach to the delivery team was key to the overall success and can be attributed to its small size and extensive communication across all areas. The communications included regular weekly meetings of focused groups with conference capabilities and monthly meetings with larger, broader groups.

**Actual FPSO Development Details and Challenges**

All of the key project success elements were put to work to get the Jubilee FPSO safely installed on location and successfully producing oil in a very aggressive 28 months from the initial award to MODEC. The work began with engineering activities managed primarily in Houston during the July, 2008 to February, 2009. In February 2009, the focus shifted to Singapore with the establishment of MODEC’s project team and the IPT’s FPSO delivery team there. A summary of the key milestones is shown in the chart in Table 1.

Late 2008 and much of 2009 was focused on building modules and conversion and life-extension work of the VLCC hull to ensure the required 20-year operating life. The hull arrived in the Jurong Shipyard in Singapore in November 2008 to begin the various upgrade and demolition works. Module fabrication was conducted at various fabrication yards throughout the Southeast Asia region with the following main contractors:

- VME Fabrication, Batam: Crude Separation, Gas Processing, Laydown, and Flare Scrubber modules.
• GSI, Singapore: LP Gas Compression Modules.
• Siemens – Megaron, Batam: E-House Module.
• MMHE Fabrication, Malaysia: Turret.

Excluding the turret, the modules totaled approximately 12,500 tons in weight. In general, the fabrication of the topside modules was completed in accordance with the aggressive schedule and delivered to the Jurong Shipyard for installation on the FPSO hull during the third and fourth quarter of 2009. The external turret was one of the heaviest ever built by MODEC/SOFEC at 2,500 tons and included capacity for 14 x 10” ID Risers and 3 x 8” OD umbilicals. The turret fabrication was subject to some special challenges due to its size, fabrication complexity, and pressure ratings. The wall-thickness of the turret piping required special materials, welding procedures and significantly greater welding time than originally anticipated. This particular challenge was met by seeking specialized sub-contractors to fabricate the pipe spools off-site using highly-trained crews working 24-hours per day over a three to four month period. Photos of the various module fabrications are shown in Figures 1 and 2.

Figure 1: Loadout of Compressor Module at GSI in Singapore

Figure 2: Lifting of Module 1S on to the FPSO in Singapore
Installation of the modules on the FPSO hull began in September 2009 with the pipe rack modules which form the center spine of the ship topsides. The six months following September saw the installation of all the remaining modules and their subsequent integration into the hull and topsides. A significant challenge was that a greater than expected number of the modules were installed on the FPSO with significant amounts of on-skid carry-over work required to achieve final mechanical completion and acceptance. This challenge was met by the FPSO Contractor electing to deliver the modules for integration on-schedule and bringing into the integration yard trained crews from the module fabrication subcontractors to finish module work while continuing with the overall integration and hook-up activities. Even though difficult to manage, the decision allowed other integration works to stay on track.

As can be imagined, there are severe space and logistical limitations on the number of workers that can be safely active at any one time on the FPSO and this required careful planning and communication between the various contractors and the joint MODEC/IPT site team. During the first half of 2010 there were days when more than 3,000 workers were active on the ship at any one time. This situation became even more complicated with the introduction of the Umbilical, Riser, and Flowline (URF) contractor who worked on the FPSO in the shipyard prior to sail-away to setup the HPU and to plan for offshore installation activities.

A core strategy utilized in the fast-track schedule activities was the plan to perform the majority of topsides and turret systems pre-commissioning onshore in the shipyard prior to sailaway. Execution of this strategy even led to decisions about when to sail the FPSO away from the yard with the sailaway delayed at least once to better coordinate all offshore schedules and ensure maximum completion of the topsides. Ultimately, the FPSO left Jurong shipyard to begin the nominal 35-day journey to Ghana on 20 May 2010, 18 months after the start of work in the shipyard.

During this 18-month period, the MODEC/IPT site team dealt with multiple challenges that could directly impact schedule or cost and often pushed the team to seek creative ways to overcome them. The first challenge to impact the team was an early change of strategy to move the planned work from a China-based to a Singapore-based approach. Although this was ultimately the decision of the IPT, the FPSO Contractor MODEC stressed that this was the only way to ensure a manageable risk to the fast-track schedule by using a well-proven shipyard contractor (Jurong) and placing all the module fabrication in closely-surrounding areas. This decision had to be made quickly in September 2008, with limited data except for the known significant commercial impact. The decision was implemented, the execution plan was modified, and post reviews indicate that this was indeed the correct decision.

At about this same time in late third quarter of 2008, just as all the final contracts and subcontracts for the FPSO were being finalized, the world financial crisis seemed to hit its peak. This impacted the ability of all parties at all levels to access cash and suitable financing terms, adding difficulty to the contractual closing of certain agreements. Close relationships between the Jubilee Partners, IPT, MODEC and various contractors allowed all work to continue through the use of multiple bridging agreements and interim financing arrangements.

A final example challenge was the complex and heavy turret construction which contained some of the heaviest and most congested piping on the FPSO, but was still delivered in-line with the fast-track schedule with limited carry-over work. An experienced turret contractor, MMHE in Malaysia, who had a close working relationship with FPSO Contractor MODEC, worked closely with the MODEC/IPT site team to meet the technical and schedule demands of this turret's fabrication. The largest challenge was getting the large diameter, heavy-wall pipe welded, installed, and tested with a very tight schedule. This required that the pipe be outsourced to a subcontractor with the additional burdens of pre-qualifying welders and procuring specialized equipment. The MODEC/IPT site team worked closely to develop and drive this alternate plan and without this additional pipe-welding subcontractor, the schedule would not have been met.

Once the pipe spools were welded, there was still the challenge of installing this heavy pipe on the small, cramped confines of the turret in a safe manner. Jointly with the FPSO Contractor, the turret sub-contractor did an excellent job of managing the challenges brought about by this interconnect pipe work, while ensuring adequate time to ship the turret to Jurong shipyard for integration with a limited and manageable amount of carry-over work. The turret was installed on the bow of the FPSO after a short two-day barge transport to Singapore on 15 February 2010. Photos of the turret during construction and installation are shown in Figures 3 and 4.
Figure 3: Crowded, large piping and valves in turret.

Figure 4: Integration of turret on to FPSO at Jurong Shipyard.

FPSO Commissioning Plan

Using lessons-learned from the FPSO commissioning challenges faced by many earlier projects, the IPT developed a comprehensive plan during 2009, for ultimately commissioning the FPSO in conjunction with the entire subsea system. The IPT developed a core commissioning team who worked closely with FPSO Contractor MODEC, and the Singapore-based IPT personnel spearheading the FPSO delivery, to create a staged commissioning plan. This commissioning plan included a mechanical completion, pre-commissioning, commissioning, and start-up phase as outlined in Figure 5. Associated with the completion of each phase is a dossier which contains the various documents and certificates which show that the defined requirements for completion of that phase for each subsystem have been met. The dossiers which document the pre-commissioning of various systems were defined as G-06 dossier by the project. The pre-commissioning phase is characterized by basic function testing, energization of equipment, leak tests, motor rotation tests, and hot loop
checks. During this phase, alignment and calibration checks are performed and lube/hydraulic oil systems are flushed, cleaned, and filled for the first time.

A critical decision of the IPT that was endorsed by the Unit Operator was that the FPSO should have all systems pre-commissioned at a minimum prior to sailaway from the shipyard. In fact, the team pushed to have as much commissioning (dynamic system testing) completed prior to sailaway as possible. Much of this early commissioning work was started and some completed during a two-week, deepwater anchorage which the Jubilee FPSO sailed to about 10 miles offshore Singapore during April 2010. Achievement of this commissioning phase results in the completion of the G-07 dossier and allows the transition from non-hydrocarbon commissioning activities into hydrocarbon start-up operation and performance testing. Early commissioning work completed during the deepwater anchorage allowed the handover of non-hydrocarbon utility systems early to the Unit Operations group.

During late 2009 and the first half of 2010, the IHUC team, along with the Unit Operations team, developed comprehensive Ready For Start-Up (RFSU) criteria and certificates that identified a multitude of conditions that must be met before start-up of any system. A typical RFSU certificate had more than 20 items that must be satisfied and approved by appropriate multi-disciplined team members before that system can be operated. Included in the RFSU certificate are the G-06 pre-commissioning and G-07 commissioning dossiers, the appropriate start-up procedures, and confirmation of clearance of all identified punch list items.

Commissioning of the FPSO occurred during late 2009 and most of 2010 through the following time periods.

- Start of Commissioning Process: November 2009
- Mechanical Completion of Topsides Systems: January to March 2010
- Pre-Commissioning of Topsides Systems: February to May 2010
- Commissioning of Topsides Systems: May to November 2010
- FPSO Topsides RFSU: 19 November 2010
- First Production of Oil: 28 November 2010

Prior to start-up, one final activity was executed to provide a fresh-eyes overview of all the FPSO systems as a final verification. This activity, called the Pre-Startup Review (PSUR) was conducted over a two month period starting in September 2010 by a multi-disciplined team comprised of individuals from each of the three partners. The PSUR used a pre-established table with more than 40 primary categories and 100 specific items to be addressed and resulted in 30 outcomes that required clarity and/or closure. Each of these outcomes were closed out as part of the RFSU requirements prior to 19 November 2010.

**FPSO Installation**

The Jubilee FPSO offshore installation was the responsibility of contractor MODEC who utilized Aker to perform the offshore work. Planning of this work was critical to ensure these activities and the installation vessels did not interfere with the subsea installation and commissioning activities. The work was planned for execution using two vessels, one for installation of the piles and one for installation and hook-up of the mooring lines. The pile installation vessel selected was the Skandi Aker which then subsequently was utilized by the Installation Hook-Up
and Commissioning (IHUC) team to provide multiple services on the subsea commissioning and topsides commissioning scopes. The Olympic Zeus vessel transported, installed, and hooked-up the nine mooring lines to the FPSO and then departed the field. Two to three anchor handling tugs were used to position the FPSO during installation.

Prior to arrival of the FPSO in the field, the Skandi Aker vessel installed all nine mooring suction piles. The FPSO arrived in the Jubilee field from Singapore on 21 June, 2010, and was soon thereafter positioned by the tugs at the appropriate location in the center of the mooring pile pattern. The installation of the first mooring line on 24 June is shown in Figure 6. By 30 June, 2010 three mooring legs had been successfully installed and connected to the turret when a pull-in line for the fourth mooring line parted, resulting in this leg falling to the seafloor. The leg was subsequently recovered, fully-inspected, and deemed to be undamaged and connected to the FPSO. All nine mooring legs were installed by 4 July, 2010 when the FPSO was handed-over to the Umbilical-Riser-Flowline (URF) contractor Technip, who would from that point forward manage the positioning of the FPSO to accommodate the installation of the risers and umbilicals into the turret. The final installation activities involved using divers to install the seawater lift hoses and aid in the installation of the floating oil off-loading hose. A decision was made by the IPT to delay these last installation activities until later when they could be sequenced between riser installation activities. Except for the dropped mooring line, the installation activities went according to schedule and actually finished within the planned schedule, which included contingency time.

Figure 6: Installation of first mooring line offshore Ghana.

Conclusions

The Jubilee FPSO, named Kwame Nkrumah, was delivered to the field 22 months after the award to contractor MODEC, thus ensuring the Jubilee project achieved its ambitious schedule to first oil. Keys to successful delivery of the Jubilee FPSO on the fast-track schedule included,

- use of a functional design basis;
- use of proven, off-the-shelf technologies and designs;
- teaming with well-established service providers;
- use of industry-accepted standards;
- project management with a small, empowered, integrated project team; and
- focus on use of the 80/20 rule for making decisions.

Despite the effort put in place to meet an aggressive schedule, the project team still encountered some significant challenges during the execution of the FPSO design, engineering, and construction. The key to successfully
resolving these challenges was the team’s ability to stay true to the execution strategy as well as develop a response plan to meet the challenges and implement it successfully.

This work highlights the importance of building a multi-discipline team driven by the clear, well-understood goals, creating a structure suited for execution, and of selecting the right Contractors for the project and building strong relationships with them. Figure 7 shows the Jubilee FPSO, *Kwame Nkrumah*, successfully installed and producing oil offshore Ghana on the Jubilee Field in 2010.

**Figure 7:** Jubilee FPSO, *Kwame Nkrumah*, successfully installed and producing oil in December 2010.