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SAUDI ARAMCO:
Offshore Construction in Crowded Waters

CHALLENGE:
Building in Active Fields

Saudi Aramco's Marjan and Zuluf increments are among the most ambitious oil and gas programs in the world. (An *increment* is an effort to increase the production capacity of an existing oil field.) The Marjan and Zuluf offshore oil fields are the second- and third-largest offshore fields in the Arabian Gulf.

Offshore construction has been identified as the biggest challenge the programs have to manage. **Multiple contractors will be working simultaneously in busy and congested oil fields**—over and around live and operating subsea and above-water facilities—which calls for extraordinary mitigation measures.

The execution of both programs in these busy and congested offshore oil fields, while maintaining normal hydrocarbon production, is one of the most complex challenges ever taken by Saudi Aramco in offshore project execution.

Saudi Aramco is a Saudi Arabian public petroleum and natural gas company. It is the seventh-largest corporation in the world by revenue (2020).

Project figures

Construction period:
2-3 years

Operational period:
20 years

CONTEXT:
Complex Existing Infrastructure

Both fields currently produce oil from around 100 offshore platforms, six offshore gas-oil separation plants, and hundreds of kilometers of subsea pipelines and cables. Each year, both fields receive additional facilities to maintain field potential and replace aging infrastructure.

Through the Marjan increment program that has already begun and the upcoming Zuluf increment program, the two offshore fields will receive tens of additional offshore oil, gas, and water injection platforms, and additional hundreds of kilometers of subsea pipelines and cables.

APPROACH:
Execution Challenges in Detail

Offshore and subsea construction work poses some of the greatest technical, logistical and safety risks in the construction world. The installation of the heavy offshore structures involves extreme heavy-lifting operations (up to 5,000 tons); the installation of extra heavy structures that cannot be lifted (in the range of 10,000 to 20,000 tons); the laying of hundreds of kilometers of subsea pipelines and cables; and the execution of specialized diving operations.

Heavy-lifting operations (photo c/o Saudi Aramco).

"Without such thorough planning and innovative handling of the risks, executing these programs wouldn't have been possible."
- Badr Burshaid, Saudi Aramco Marjan and Zuluf Program Director

The risks associated with each activity often pose real danger to properties and personnel working in these offshore oil and gas fields. These risks multiply drastically when working within existing operational fields that are already busy with ongoing drilling and maintenance activities.

The risks and challenges of executing in busy, producing offshore fields can be narrowed into three main categories:

1. Marine traffic and logistics. Both the Marjan and Zuluf fields are operating fields. The fields currently run busy production operations with a heavy presence of boats to support operations, maintenance and security personnel roaming around the fields. In addition, the potential projects add a substantial number of marine vessels. **It is estimated that both fields have an average of 100 boats or barges present daily**.

2. Interface with subsea assets. Another challenge associated with busy offshore fields is the complex mesh of subsea pipelines and cables connecting the existing/producing facilities. The Marjan field, for example, is an area that is 20 km wide and 30 km long. There are hundreds of kilometers of existing subsea pipelines and cables connected in this small geographical area, which already represents a highly complex achievement. **Adding hundreds of kilometers of additional subsea pipelines and cables within the same area poses significant logistic and safety challenges.** The new lines will need to cross existing subsea pipelines and live subsea cables. Any miscommunication or faulty installation can lead to equipment damage, harm to personnel, or interruption of ongoing operations.

3. Offshore construction costs and logistics. Executing normal offshore construction work is much more expensive than similar construction activities onshore. Many of the required resources are specialized barges that are rare around the world. There are only a small number of heavy-lift barges that can lift an excess of 5,000 tons, and only three or four cable-lay barges that can lay the required length of cable in one run between the coastline and the Marjan field. The cost and logistical challenges are even greater when trying to execute these offshore construction projects in busy fields with the required safety and precaution measures.

The project management team within Saudi Aramco realized these challenges at the early stages of planning for the increment programs.

“The planning stage for Marjan and Zuluf programs was considered the most important stage of the development,’ said Badr Burshaid, Saudi Aramco Marjan and Zuluf Program Director. “Saudi Aramco realized the risks associated with the huge construction operation in these operational offshore fields and the project team spent the required time to make sure every aspect is covered. Without such thorough planning and innovative handling of the risks, executing these programs wouldn’t have been possible.”

The Marjan and Zuluf increment projects department worked with the integrated project team members from all relevant Saudi Aramco organizations to plan for and mitigate the identified risk categories. The teams conducted thorough analyses and designed early mitigation measures, utilizing the latest technologies to ensure safe execution of the offshore construction activities with no interruption to the ongoing production and drilling operations.

SOLUTIONS:
A Three-Pronged Approach

The project management team worked in close coordination with the operations and marine departments to properly plan and implement many mitigation measures addressing the huge challenges.

The mitigation measures span over almost all project execution phases. Some of these measures were implemented as part of awarded contracts, while others are being implemented in the engineering and detailed design phase. The remaining will be implemented in the construction phase.

Through proper planning and front-end marine traffic and risk studies, the team identified and implemented multiple measures to mitigate the risks. These measures included:

- *Technical solutions*, such as utilizing only Class 2 and 3 dynamic positioning (DP) systems.

- *Reduction of complexity* through the implementation of renewable energy solutions and elimination of subsea cable and pipeline crossings.

- *Administrative measures* associated with the fields' management and marine vessel control, including the establishment of dedicated navigation channels and anchorage areas.

The team kicked off a study to model and analyze the marine traffic, taking into consideration the ongoing operations and the forecasted increase in activities during the execution of the increment programs. The study utilized the latest computer modeling to generate heat maps and risk areas for both offshore oil fields.

Heat maps were then utilized to identify the major contributors to increases in traffic and risk factors. The team then conducted series of brainstorming sessions to identify the measures that could be implemented to reduce the risks.

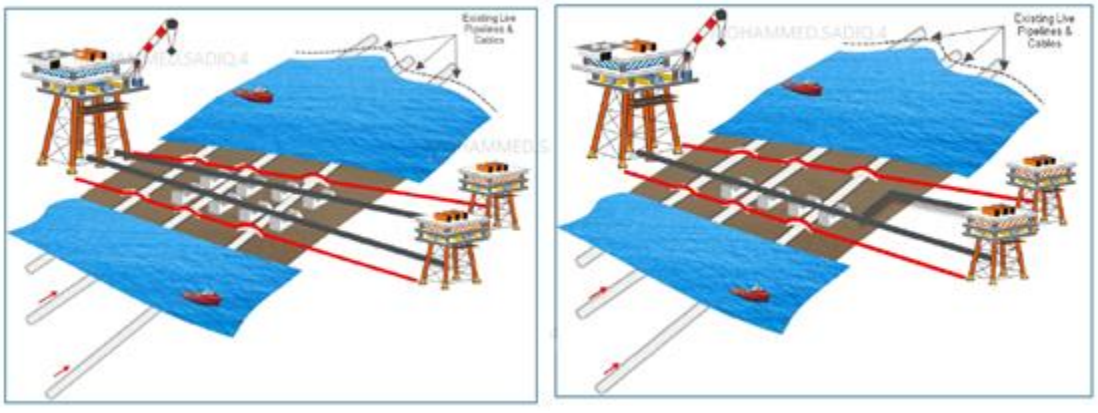
Some of the major measures implemented included:

Reducing the complexity of subsea cables. The increment projects department analyzed the power requirements of the programs' relatively low-power- consuming facilities (such as the water injection platforms) and adapted the use of solar panels in lieu of running new subsea cables. **The decision eliminated tens of kilometers of subsea cables required to power the offshore platforms**.

As such, this design directly addressed and mitigated all three risk categories by significantly lowering the number of subsea cables (reducing the subsea interfaces and crossings), reducing the number of required cable-lay vessels (contributing to lowering the marine traffic), and providing more cost-effective design. **The use of renewable solar energy is also more environmentally friendly than the traditional subsea cable approach**.

Reducing complexity of subsea pipeline design. The traditional design of offshore production platforms uses a direct subsea pipeline from each production platform to a collecting platform known as a tie-in platform. The tie-in platform collects the production from multiple (8–10) production platforms and sends the gathered production to gas-oil separation plants for processing. This typically requires hundreds of kilometers of pipelines to transfer the produced hydrocarbon to the processing facilities. Moreover, each pipeline requires continuous maintenance and scraping operations to preserve and prevent corrosion. **The Marjan and Zuluf increment projects department has designed the subsea pipeline configuration with a multilateral approach requiring only one pipeline for every group of platforms**. The pipeline starts from a leading platform while the others connect join-ins using a lateral approach.

The project has also adapted the use of flexible lines for lateral connections. The flexible lines technology provides an excellent nonmetallic alternative to the traditional rigid carbon steel pipelines. Although flexible lines may have limitations in length and size for longer runs, they work perfectly in lateral connection and provide scraping-free corrosion resistance. **This approach eliminated tens of kilometers of subsea pipelines and crossings between the new pipelines and the existing subsea pipelines and cables**. The number of marine vessels required to install the pipelines was also reduced, in addition to reducing marine traffic during normal field operations.



Modified Subsea arrangements (photo c/o Saudi Aramco).

Contracting strategies. The project team took several steps to properly plan the construction activities and reduce or eliminate risks during the construction phases. From a planning perspective, the contracting strategies of the projects have taken marine traffic and crossing risks into consideration and adapted a geographical-area zoning strategy. **The contracting strategy is designed to reduce overlapping and interfacing between construction contractors**, and to allow each construction contractor full access to their construction sites independently, with a dedicated marine channel that eliminates the need to cross the busy field center.

Construction simplification. The selection of the platforms' locations and the routing of the subsea pipelines and cables planned and selected to provide the lowest possible number of crossings. Wherever possible, **the team used double subsea crossings, where one crossing structure is deployed on the seabed to protect the existing adjacent subsea pipelines and cables before crossing them with new ones. This significantly reduced the number of overall crossings, providing cost and risk avoidance during offshore construction.**

The design of all heavy, large and complex facilities was planned with the purpose of simplifying offshore construction. The team designed the extra-heavy platforms (weighing 5,000 tons or more) to be installed using float-over techniques that employ semi-submersible barges rather than cranes. **Float-over installation eliminates the need for rare, expensive and massive extra-heavy-lift barges**. The float-over installation method is a much simpler installation technique that uses fewer marine resources.

Float-over construction technique (photo c/o Saudi Aramco).

The Marjan and Zuluf projects adapted the use DP vessels in all construction operations. The use of DP vessels eliminates the need to deploy anchors to control the movement of barges and the installation work. Instead, DP systems rely on satellite GPS technology to control the barge's thrusters and adjust the position and movement of the barge automatically. **This eliminates massive anchoring work on the already congested seabeds, and significantly reduces the risk of dropping anchors on live subsea pipelines and cables and any potential damage to personnel, assets, and the environment**.

Marine management and mitigations. The Saudi Aramco marine department has also proactively implemented several operational control measures to ease movement and reduce traffic in the busy offshore fields. The marine department increased the number of anchorage areas in both fields from two to four, providing safe designated areas for the vessels/barges to shelter during bad weather periods, and avoiding the risk of damage to existing (or new) subsea and topside facilities.

The marine department also adapted and approved additional designated navigation channels for vessels to move between fields and to and from shore. **These channels work like superhighways and control the marine traffic through known, safe, and continuously monitored lanes to avoid scattered traffic all over the fields in the Arabian Gulf.**

Enhanced master training. Saudi Aramco realized the need to focus on the vessels' masters and mates to make them appreciate the changes taking place in the offshore fields. **An enhanced training is being developed for the masters and mates of vessels engaged in the increment programs. The training will allow these key personnel to make better decisions and improve situational awareness of increment and baseline vessel traffic activities.**

Marine traffic control. During construction of the increment programs' facilities, the Saudi Aramco project management team, along with the marine and operations departments, is planning to deploy a state-of-the-art marine control center (MCC) to continuously monitor, control and direct the marine traffic associated with ongoing operations and new drilling and construction activities.

Similar to flight control systems in busy airports, the MCC will be directly connected to the vessels tracking system that will be mandated on all marine vessels working on Saudi Aramco fields. The human-computer integrated staff will be planning and monitoring all marine traffic, and will have live feeds of the subsea activities, heavy-lift and float-over installations, and diving operations.

PATH FORWARD:
Execution Timeline

The Marjan increment is slated for completion in 2025.

Construction on the Zuluf increment will begin in 2024 and is slated for completion in 2027.