DEEPWATER STRUCTURE REMOVAL ANALYSIS

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ABOUT THE AUTHOR

Alan Stokes has 45 years of management and project engineering experience within the international offshore and shipbuilding industries. Worked directly on 33 oil and gas fields in the North Sea and with first-hand knowledge of a further 23. Now Global Head of Offshore Decommissioning for WorleyParsons.

Alan is a leader in the decommissioning industry. For the last 6 years he has gained extensive experience in managing cost estimation, scheduling for all aspects of decommissioning and whole platform removal and subsea equipment recovery.

Alan is a member of the Oil and Gas UK Decommissioning Work Group, an industry and government joint working group, where he chairs the topic on Efficient Execution.
Introduction

Decommissioning offshore structures in water depths greater than 300m is one of the biggest challenges the decommissioning industry faces. Each structure is unique and irregular in shape. As a result, first principles will need to be utilized to solve the analytical issues created by drag, added mass and wave drift to lift the structure from the seafloor to the surface and transport to an onshore disposal site.

During each stage of the structure removal, all the way through to onshore dismantling, the methodology used must ensure safety, not impact the environment and at minimum cost. Often, decommissioning is viewed as a non-value adding requirement. However, it can also be used as an information gathering experience where lessons learned can be applied to the design of future projects, reducing future decommissioning liability.

This whitepaper aims to describe the issues, outline the challenges and identify the areas in which technology needs to be developed to effectively remove structures in water depths greater than 300m.

Philosophy

First a philosophical question. Why should we remove structures that have been safely in place and structurally strong for the last twenty or so years of the life of the field? Three reasons are listed here:

- A clear water column for ships to pass safely, but this clear water column is only 55 m deep.
- Fishermen insist on removal as the sea bed structures may snag their nets.
- Non-governmental organizations require the sea bed to be cleaned to its state prior to development of the field.

Past experience

There is almost no experience of decommissioning and removal of large structures from deepwater locations. Only one large structure has been decommissioned and removed from the sea bed. Many well heads weighing up to 30 tonnes have been removed. In 2012, the TOGI template was removed from the sea bed in 302m of water (Table 1) using the Saipem 7000 heavy lift crane vessel.
TABLE 1: THE TEMPLATE STATISTICS

<table>
<thead>
<tr>
<th>Location:</th>
<th>North Sea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Depth:</td>
<td>302m</td>
</tr>
<tr>
<td>Weight:</td>
<td>1615 Tonnes</td>
</tr>
<tr>
<td>Length:</td>
<td>54m, Width: 35m High: 13m</td>
</tr>
<tr>
<td>Foundation:</td>
<td>4 piles 1219mm diameter 38mm thick and 72m long</td>
</tr>
</tbody>
</table>

The challenges of the decommissioning and removal work were:

- The design of the lift rigging as the template weight was increased by an unknown quantity of cement.
- The underwater wet tow of 117 miles.
- Cleaning of the flow lines to the platform and the piping on the template.
- Minimize environmental disturbances to the sea bed.
- Ensuring the Integrity of the structure and lift points prior to the lift.

The Saipem 7000 crane vessel lifted the template from the sea bed and towed the template underwater to the disposal site in Norway.

Decommissioning Cost Drivers

Decommissioning of an offshore structure is not only the removal of the structure. A decommissioning project has several stages and decisions on the decommissioning method which will affect the costs and duration of these stages. For example a Floating Production, Storage and Offtake oil tanker (FPSO) could be taken to a ship repair yard for scrapping hence reducing the costs of cleaning and removing hydrocarbons as this cleaning work can be done alongside the ship repair quay with ballast water cleanup facilities and permits for hazardous waste already in place.

The main stages of all decommissioning projects follow sequentially from the date of Cessation of Production (see Table 1). During the second stage, the bulk of hydrocarbons in the process plant and storage tanks are removed by the production team. Next the Engineering Down of the facility ensures the plant is safe for the cleaning to commence. Engineering Down tasks include the release of trapped pressure in hydrocarbon pipes, earthing the electrical networks and disconnecting the batteries. Detectors with radioactive isotopes are removed at this time. Then the remaining hydrocarbons adhering to the walls of the pipes and pressure vessels are removed by water and chemical cleaning so that the preparation for removal can commence. Preparation work is the cutting of pipes and electrical cables and installing the lifting points. Finally the steel structures and modules are removed and taken to an onshore yard for reuse, recycling or as a last resort landfill. Each stage has a driver for the costs as listed in Table 1. The Naval Architect should seek to reduce these drivers in his solutions in order to minimize the costs.
### Table 2: Stages of a Decommissioning Project

<table>
<thead>
<tr>
<th>Project phase</th>
<th>Cost driver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation for decommissioning</td>
<td>Number of studies</td>
</tr>
<tr>
<td>Operations after Cessation of Production</td>
<td>Number of people on the platform</td>
</tr>
<tr>
<td>Engineering down of process plant</td>
<td>Disposal route for hazardous material</td>
</tr>
<tr>
<td>Removal of hydrocarbons and cleaning</td>
<td>Standard for hydrocarbon removal</td>
</tr>
<tr>
<td>Cutting of pipes, steel and cables for removal</td>
<td>Duration of cutting work</td>
</tr>
<tr>
<td>Lift and removal</td>
<td>Size and duration of the crane vessels</td>
</tr>
<tr>
<td>Onshore disposal</td>
<td>Proximity of disposal yards to the oil field</td>
</tr>
</tbody>
</table>

### Decommissioning Costs

At present the costs for decommissioning a structure in deepwater are not estimated in detail. For this paper I have prepared my estimate for the removal costs based on my experience and the Oil and Gas UK decommissioning cost databases. My cost analysis in figure 2 excludes the well plug and abandonment work as the Naval Architect is not involved in this part of the decommissioning project. The percentage costs for decommissioning and removing a platform and its associated sea bed templates is shown in figure 1.

### Figure 1: Pie Chart for Deepwater Decommissioning Costs

- **Removal**: 35%
- **Preparation for removal**: 14%
- **Operations costs**: 13%
- **Engineering down**: 10%
- **Cleaning**: 9%
- **Preparatory engineering**: 8%
- **Project management**: 8%
- **Onshore disposal**: 3%

### Types of Deepwater Structures

Oil and Gas is being found in deeper waters throughout the world. In 1977 fixed structures were installed in 300m in the Gulf of Mexico for the first time. Now in 2014, deepwater structures are in place or will be in place in the next three years in:

<table>
<thead>
<tr>
<th>Location</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gulf of Mexico</td>
<td>2200m</td>
</tr>
<tr>
<td>Eastern Malaysia</td>
<td>490m</td>
</tr>
<tr>
<td>Northern Norway</td>
<td>1300m</td>
</tr>
<tr>
<td>South Atlantic, Angola</td>
<td>1500m</td>
</tr>
<tr>
<td>South Atlantic Brazil</td>
<td>1500m</td>
</tr>
</tbody>
</table>
The average life of an oil field is between 20 and 40 years so the first deepwater structures in the Gulf of Mexico are planned for removal soon. The challenge is to remove the structures safely and at a minimum cost.

The two main groups of structures are the fixed structures and the compliant structures.

**Removal of fixed steel structures**

The fixed steel piled structure cannot be removed in the reverse way it was installed. Reverse installation requires a deballasting operation and a Heavy Lift crane vessel to lift the structure from the sea floor. Then the ballast water has to be moved and flooded members emptied to rotate the structure to a horizontal floating position for the tow to shallow water. An obvious solution but impractical as this requires the same expensive crane vessels that were used to install the structure and depends on the ballast piping, valves and tanks to be in place and reusable after twenty years of life.

So the challenge for the Naval Architect is not to use the expensive semisubmersible crane vessels. Three techniques have been developed that could be used to remove a Deepwater structure.
● **Buoyancy tanks:** Temporary buoyancy tanks are fastened to the surface piercing members of the jacket. They are deballasted to lift the jacket from the sea bed. The jacket can be towed in a vertical orientation to shallow water for dismantling. Aker used the buoyancy tanks for the removal of the Frigg jacket in 2012 (reference Norwegian Petroleum Forum Decommissioning conference 2012)

● **Versatruss lift frame:** A novel lift frame carried by two barges was used to lift 4,000 tonne structures from the sea bed in the Gulf of Mexico (reference www.vbar.com)

● **Salvage lift and tow underwater:** The hull of the Kursk submarine was lifted from the sea bed by Strand jacks on a cargo barge. The hull was then carried under the barge to sheltered water (Reference Raising the Kursk video on Youtube.com)

The other alternative is to cut the structure underwater and lift out in pieces with a Heavy Lift Crane vessel or Dive Support Vessel. Piecemeal cutting into lifts of 200 to 2000 tonnes has been done for structures up to 150m water depth but it is time consuming. For Deepwater platforms of up to 50,000 tonnes, the durations for the cut and lift work would be eye wateringly long and expensive. Technology is available for underwater cutting, but the diamond wire and mechanical shear tools are cumbersome. Although the cuts are done quickly, much time is spent in setting the tool in place and then lifting the cut component away.

It is up to us in the decommissioning industry to think of new solutions for fast removal of large piled structures.

**Removal of compliant structures**

The first part of the removal is easy. The restraints of tethers or anchor ropes are disconnected and the compliant structure is deballasted. Both these operations are simple and require little engineering, provided the release and ballasting systems have been maintained throughout the life of the field. Bitter experience, however, shows that this is unlikely to be the case. The Naval Architect will have to use expertise to engineer safe alternative procedures. The final stage is to tow the compliant structure to the disposal site and this stage is a conventional towage operation.

Spar structures create a new set of challenges. The deep operating draught of a Spar will present a challenge as the Spar will have to be ballasted to the horizontal position for the tow to shallow waters.

Before the structure can be rotated the topsides will have to be lifted off or dismantled. The challenge is not only to ballast for a safe horizontal tow, but also to sea fasten all the plant and equipment for the new angle of tow.
The removal of the sea bed foundations and templates is the final offshore operation. As Statoil found when removing the TOGI template the lift weight is an unknown without detailed surveys. As part of the drilling operations and well operations cement spills out of the wells onto the seabed. Spillage is needed to ensure complete cement bond has been made. The spare cement will lie on around and inside the template. Engineering assumptions and surveys are needed to estimate the lift weight and hence design the lift rigging.

**Other issues**

The previous paragraphs have discussed the challenges and solutions of the removal. However physical removal is only 35% of the total cost. Cleaning the hydrocarbons from the process plant / piping and making the plant free from volatile hydrocarbons at a deepwater location accounts for about 20% of the cost. The challenge here is the pressure and temperature at the sea bed. The temperature drop from the flowing oil to the sea bed temperatures can cause Asphaltenes to build up on the walls of the vessels, pipes and well tubulars. These require chemical and high pressure cleaning to remove and reach the standard of cleanliness required. Oil and gas wells in Deepwater are high pressure and high temperature so the pumps for the flushing and cleaning fluids will be high pressure. High pressure pumps have a low flow rate so cleaning may take time and high expense.
Gaps in the technology

We are fortunate that Industry have developed and benchmarked analytical software to cover most aspects of the removal work. The software was developed for the installation work and will need to be benchmarked for removal work.

Cutting tools need further development. Present tools can cut in water depths to 200m with diver support. Deepwater means all tools have to be operated remotely. Cutting is a lengthy task as it takes one day to set up and remove a tool to execute a cut lasting five minutes. An Ultra High Pressure Water jet cutting tool was developed for the cutting of the Macondo oil well in 1430m of water. However it was only used a few times. Diamond wire cutting is frequently used but the wire can snag on the steel and the easy freeing operation in shallow water, using the flexibility and adaptability of the diver, is not available in Deepwater.

Removal of steel pipelines, flexible pipes and umbilicals is untried in Deepwater. After cessation of production, recovery is uncertain as the structural integrity may have been compromised during operations and end connections may not be robust. The only recovery technique available is the reverse installation method using the same construction pipelay vessel.

Mass excavation tools to remove soil and cement from around the structure are not available. Excavation is needed to allow access for the tools to cut the pile foundation and then have confirmation that the structure is clear and ready to lift. Mass excavation is needed as the sea bed soils are unconsolidated and the repose angle of the soils after excavation is small. Thus a lot of soil has to be removed to create a shallow hole.

Gaps in knowledge

To remove all traces of a Deepwater structure from the sea bed has high cost and risks to people. Derogation (leaving steel on the sea bed) is a pragmatic alternative. We need to make the scientific case backed up by evidence and then develop the political case. My search of the literature found very little quantification of deepwater fisheries and very little evidence of the long term effects of structures on the marine environment. More data must be gathered to make the scientific case for derogation. The political and safety issues will require much dialogue with all stakeholders after quantification of the benefits of derogation.

Way Forward

The United Kingdom and Norway have accepted derogation for concrete structures and pipelines in the North Sea. Permitting derogation for the templates, anchor foundations and the lower part of steel piled structures will reduce risks to offshore teams and save money. We must expand derogation to all Deepwater Structures.
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References

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