Ultra-Deepwater Dry Tree System for Drilling and Production in the Gulf of Mexico
Phase 1, Final Presentation

10121-4405-02
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DNV GL

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Houston, TX
Various Floater Types
## Wet Tree vs. Dry Tree

<table>
<thead>
<tr>
<th>Subject</th>
<th>Wet Tree</th>
<th>Dry Tree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drilling expenses</td>
<td>High, requires MODU</td>
<td>Lower, drilling directly from floater</td>
</tr>
<tr>
<td>CAPEX (facilities)</td>
<td>Lower, smaller/simpler hull</td>
<td>High, larger and more complex floater/hull</td>
</tr>
<tr>
<td>Flexibility in development</td>
<td>Minimal floater impact</td>
<td>Somewhat restricted to floater layout</td>
</tr>
<tr>
<td>TTR/floater interfaces</td>
<td>N.A.</td>
<td>Relatively complex interfaces, floater dependent.</td>
</tr>
<tr>
<td>SCR/floater interfaces</td>
<td>Traditional</td>
<td>Traditional</td>
</tr>
<tr>
<td>Structural; hull and topside</td>
<td>Traditional</td>
<td>More complex, floater dependent</td>
</tr>
<tr>
<td>Offshore work/flexibility</td>
<td>Less effort</td>
<td>Some heavy lifting may be required</td>
</tr>
<tr>
<td>Flow assurance</td>
<td>Potentially long flow path/lines</td>
<td>Shorter flow path</td>
</tr>
<tr>
<td>Safety (shut-in location)</td>
<td>At seabed, hence low risk to personnel</td>
<td>In floater well bay, close to personnel</td>
</tr>
<tr>
<td>Access to reservoir</td>
<td>Requires MODU, i.e. costly</td>
<td>Direct access from floater reduces well intervention cost and higher potential to improve reservoir management</td>
</tr>
<tr>
<td>Field Development Cost</td>
<td>High, requires MODU</td>
<td>Less costly, can be done from floater</td>
</tr>
</tbody>
</table>
Motion Characteristics of Dry Tree Units

- TTRs are used - Controlled vertical motion is essential for DTU
- TLP has superior/low heave motion
- DDF/Spar favorable heave motion
- Traditional semi has higher heave motions
- Actual geographical area crucial in this context (absolute motions)
Motion Characteristics

Natural Periods of Motion

- Fixed/Vertically Moored
- Spread Moored

Design Wave Energy

Typical 100-Yr Design Wave Spectrum
Advantages of Dry Tree Semi

- Drilling, completion, workover and production from the same floater
- Once discovery is made, less dependent on MODU
- Direct access into reservoirs from the unit
- Increased potential for deepwater development, especially for marginal fields
- Install and commission topsides at a quayside location
Various DTS Concepts

- Deep draft (fixed/variable)
- Added mass/damping plates
- New column configurations

Courtesy of FloaTEC and KOMtech

Courtesy of Kvaerner

Courtesy of HOE
Comparisons of TTR Strokes

Tensioner stroke (ft)

- TLP
- DDF/Spar
- DTS

Graph showing comparisons of TTR strokes with different systems and their stroke lengths.
Objective

• Further develop & mature two floating system concepts suitable for drilling and production in ultra-deepwater using dry trees

• Two concepts –
  • HOE Paired Column (PC) Semi-Submersible
  • KFD Deepwater Dry Tree Semi

Primary Contractor:
DNV GL – Det Norske Veritas USA (Inc)

Subcontractors:
HOE – Houston Offshore Engineering
KFD – Kvaerner Field Development
Both concepts have gone through development
- HOE – RPSEA Project 07121-1408b, Phase 1 & Deepstar Project CTR 10406
- KFD – Deepstar Project CTR 10404

Key Design Focuses:
- HOE:
  - Potential VIM due to new hull form
  - Riser tensioner assembly
  - Quayside integration
- KFD:
  - Long stroke riser tensioner system (35 ft stroke range)
  - Potential VIM
  - Engineering work to document global performance, global strength, stability etc.
Scope

• Conduct VIM test
• Develop riser tensioner and its entire assembly
• Further engineering design
• Conduct AiP for each concept
• Conduct Technology Qualification of riser tensioners
• Conduct scoping cost estimate and prepare level two project schedule for delivery of proposed system
• Project duration = 15 months (originally)
HOE Concept

- Paired Column Semi with 4 inner columns, 4 outer columns
- Design draft = 175 ft
- Motions of paired column semi result in top-tension riser strokes similar to existing units

(Picture courtesy of HOE)
KFD Concept

• Conventional 4-column deep draft semi hull, Quayside integration

• Design draft = 145 ft

• Adopt RAM style tensioning system
## Schedule vs. Original Baseline

<table>
<thead>
<tr>
<th>Task</th>
<th>KFD</th>
<th>HOE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Kick-off with RPSEA</td>
<td><strong>10/15/2012</strong></td>
<td><strong>10/15/2012</strong></td>
</tr>
<tr>
<td>Project Management Plan / Technology Status Assessment / Technology Plan</td>
<td><strong>11/15/2012</strong></td>
<td><strong>11/15/2012</strong></td>
</tr>
<tr>
<td>Complete Design Basis</td>
<td><strong>11/15/2012</strong></td>
<td><strong>11/15/2012</strong></td>
</tr>
<tr>
<td>Complete PreFEED Engineering</td>
<td><strong>06/30/2013</strong></td>
<td><strong>02/28/2013</strong></td>
</tr>
<tr>
<td>Approval in Principle</td>
<td><strong>10/30/2013</strong></td>
<td>Report to be completed</td>
</tr>
<tr>
<td>Complete Hull VIM Model Test</td>
<td><strong>04/19/2013 – 04/26/2013</strong></td>
<td><strong>05/03/2013</strong></td>
</tr>
<tr>
<td>Complete Riser Tensioner Model Test</td>
<td><strong>04/31/2013 – 10/30/2013</strong> (based on availability)</td>
<td>Report to be completed</td>
</tr>
<tr>
<td>TQ of Tensioner Assembly</td>
<td><strong>11/30/2013</strong></td>
<td><strong>05/30/2013</strong></td>
</tr>
<tr>
<td>Project Final Presentation</td>
<td><strong>Latest Nov. 2014</strong></td>
<td><strong>Latest Nov. 2014</strong></td>
</tr>
<tr>
<td>Project Close-out</td>
<td><strong>12/27/2013</strong></td>
<td><strong>Extended to Dec. 30th, 2014</strong></td>
</tr>
</tbody>
</table>
Baseline vs. Actual Cost

**Project Costs**

- **Cumulative Costs** vs. **Project Month**
- **Planned** and **Actual** costs are represented with distinct lines.

**Invoiced Cost Share**

- **Cumulative Costs** vs. **Project Month**
- **Planned** and **Actual** invoiced costs are represented with distinct lines.
Baseline vs. Actual Cost

Invoiced Technology Transfer Costs

- **Cumulative Costs**
  - Planned
  - Actual

- **Project Month**
  - 1 3 5 7 9 11 13 15 17 19 21 23
Hull Configuration Changes

- Due to revised Design Basis:
  - LQ size increased to 200 people
  - Topsides facility weight increased to 6000 st
  - SCR layout changed

Design, Engineering Study performed and documented
Kvaerner Long Stroke Riser Tensioner Model Test

Test Objectives:
• Investigate functional performance of a long stroke (35 ft) RAM style tensioner at operation, extreme and survival environmental conditions.
• Simulate removal and re-installation of a cylinder of the tensioner during operation.
• Identify potential design issues and risks.

Test Program:
• Used a 1:5 scale tensioner model.
• Include 20+ cases at various conditions.

Test Schedule:
The tensioner model test was performed in June 2013 at Maritime Hydraulic facility in Canada.
Key Findings of Riser Tensioner Test

The Kvaerner proposed long stroke riser tensioner system is able to

- Perform the required functions at operation, extreme, and survival conditions;
- Withstand severe loads at tensioner bottom-out or top-up condition under 1000-yr hurricane survival storm;
- Continue operation while removing and re-installing one of the cylinders.

(Picture courtesy of Kvaerner)
Following a systematic risk based approach like DNV’s qualification process

Involves document review, workshop (attended by SME) etc.

Discuss concerns/failure modes/consequence/ High level risk ranking

Two levels of qualification:

First, Evaluation and Qualification of the floater Concept, and

Then, Qualification for new Components/System

Provides confidence to maturity of new technology
Riser tensioner system is considered an extension of existing technology. A Technology Qualification process per DNV-RP-A203 is followed.
Technology Qualification of Riser Tensioners

Riser Tensioner General Arrangement for Kvaerner Deepwater Dry Tree Semi (DWDTS):

(Picture courtesy of Kvaerner)

(Picture courtesy of Kvaerner)
A conceptual design for a RAM-style tensioner has been presented by KFD.

The concept can be brought to comply with the specified functional requirements and can thus be considered to be qualified for the intended purpose.

The above does not signify a final verification by DNV GL of a design. Detailed drawings have not been available to DNV GL. Some components have not yet been fully specified but can most likely be sourced. It is assumed that a final design in accordance with applicable codes, standards and good engineering practice will be carried out and subjected to verification.
Kvaerner DWDTS Hull VIM Model Test

Test Objective:
• Investigate VIM characteristics and effects of a 4-column dry tree semi-submersible.

Test Program:
• Used a 1:60 scale hull model
• Covered five towing directions, and 9 reduced velocities for each direction, plus a few sensitivity cases.

Test Schedule:
• The hull VIM model test was performed in April 2013 at Force Technology facilities in Denmark.
For the Kvaerner proposed dry tree semi based on VIM model test results (VIM lock-in between $Ur$ 5.5 to 8).
Hull Configuration Changes Due to:

- Revised Design Basis:
  - LQ size increased to 200 people
  - Topsides facility weight increased to 6000 st
  - Wellbay layout changed to 3x5
  - SCR layout changed

- Design Optimization

Design, Engineering Study performed and documented
Project Progress – HOE Concept

VIM Model Test Completed

Technology Qualification of Tensioner System completed

Quayside Integration Feasibility Study completed
VIM Model Test Status

- 4 week VIM Model Test campaign at MARIN during June 2013
- Model scale of 1:54, 180+ VIM runs
- 6 headings, 4 hull configurations
- VIM Model Test Summary Report issued

VIM response of PC Semi is lower when compared to published conventional deep draft semisubmersible data.
Major Achievements – HOE Concept (cont’d)

Riser Tensioner Qualification Status
- Conducted strength and fatigue analysis to validate riser tensioner design
- Technology Assessment Workshop completed
- Threat Assessment workshop completed
- Final report (Technology Qualification) issued by DNV GL, Norway

Technology Qualification of Riser Tensioner system completed

(Picture courtesy of HOE)
Major Achievements – HOE Concept (cont’d)

Quayside Integration by Kiewit Heavy Lifting Device

Quayside Integration at CIMC Raffles

Feasibility Study of Quayside Integration of topside completed
Major Achievements – DNV GL

- All document review is completed.
- A workshop involving Subject Matter Specialists from the industry was held on Apr. 10th, 2014.
- Final report is being drafted.
### Conceptual Risk Assessment - example

<table>
<thead>
<tr>
<th>Critical Issues</th>
<th>Concerns</th>
<th>Failure mode / Consequence</th>
<th>Cons.</th>
<th>Likelihood</th>
<th>Risk Rank</th>
<th>Documented?</th>
<th>Final Risk Ranking</th>
<th>Later Design Stage</th>
<th>Comments/Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Global Performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Rigid Body Motion</td>
<td>Different range of motions from traditional semi and other dry tree units</td>
<td>Excessive motions, excessive riser responses, may cause riser failure</td>
<td>Md</td>
<td>O</td>
<td>M</td>
<td>Y</td>
<td>L</td>
<td>Global performance analysis, model test correlation report</td>
<td>DNV independent analysis has concluded similar results.</td>
</tr>
<tr>
<td>2. VIM</td>
<td>New configuration, may be subject to VIM</td>
<td>Potential risers/mooring system failure due to movement outside their design limits</td>
<td>Md</td>
<td>L</td>
<td>H</td>
<td>Y</td>
<td>L</td>
<td>Mooring System Design Report</td>
<td>VIM model test completed, confirms that the A/D used in analysis is reasonable.</td>
</tr>
<tr>
<td>3. Airgap</td>
<td>Required to meet the 100 year and 1000 year airgap design criteria</td>
<td>Structural failure due to wave impact loads</td>
<td>Mj</td>
<td>O</td>
<td>H</td>
<td>Y</td>
<td>L</td>
<td>Global performance analysis, Wave basin model test correlation report</td>
<td>1000 year hurricane, wave is clear of bottom of the deck. Truss hanging below lower deck is to be designed to withstand wave impact loads. DNV independent analysis indicate similar results.</td>
</tr>
<tr>
<td>4. Sensitivity to deckloads</td>
<td>Flexibility on the limit on deck loads and different throughput with more vulnerable conditions than a conventional semi</td>
<td>Potential resizing</td>
<td>Mn</td>
<td>S</td>
<td>L</td>
<td>P</td>
<td>L</td>
<td>Further sensitivity study wrt deck loads</td>
<td>Two payload cases have been studied under RPSEA Phase I project and current RPSEA project.</td>
</tr>
<tr>
<td>5. Sensitivity to riser stiffness</td>
<td>Has different number of riser cases been fully considered in design?</td>
<td>Excessive motions due to different riser vertical restoring stiffness</td>
<td>Md</td>
<td>O</td>
<td>M</td>
<td>P</td>
<td>L</td>
<td>Further sensitivity study wrt riser stiffness</td>
<td>Riser report</td>
</tr>
</tbody>
</table>
Conceptual Risk Assessment Workshop

- Attended by most oil majors, incl. Chevron, Statoil, Exxonmobil, Total, BP, Shell and other subject matter specialist incl. Stress, 2H etc.
- Systematically evaluated various disciplines for each concepts
- No major show stoppers identified
- Some suggestion for further engineering study at design phase
Conclusions

Value for the Industry

- Advanced 2 DTS concepts to be project ready
- Independently evaluated 2 DTS concepts
- Systematically identified risks and mitigations
- Technology qualification for critical components
- Suggested way forward for project phase

Conclusions: Value for the Industry
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