Wet vs. Dry Tree Selection in Deepwater Developments

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Introduction

**Wet Tree vs Dry Tree Completion Systems:**

- One of the key decisions offshore field development planning is selection of a wet tree or dry tree completion system.
- Both systems have been successfully used in deepwater developments. Dry tree systems up to 1,707 m (5,600 ft) and wet tree systems up to 2,926 m (9,600 ft).
- The influence on field development decisions, drilling and intervention methods, facility size and operational issues are reviewed in order to provide guidance on completion system selection.
- The impact of dry tree vs. wet tree system selection on development concept and floating facility type selection was examined through a U.S. Gulf of Mexico field development case study in 1,219 m (4,000 ft) water depth.
Progression of Deepwater Development Technology:

- Auger TLP: 1994 First dry tree production/drilling TLP in the GoM at 884 m (2,900 ft).
- Devil’s Tower Truss SPAR: Deepest dry tree platform at 1,707 m (5,600 ft), GoM.
- Perdido SPAR: Deepest floating wet tree platform at 2,438 (8,000 ft), GoM.
- Cascade & Chinook FPSO: First FPSO in GoM wet tree platform at 2,590 m (8,500 ft).
- Dry to wet water depth cutoff is between 1,524 m (5,000 ft) and 1,829 m (6,000 ft.)
Dry Tree Systems

Major Components:

- Top Tensioned Riser System (TTR)
  - Drilling Riser
  - Production Riser
  - Subsea Wellhead
  - Tieback Connector
  - Riser Joints
  - Buoyancy Modules
  - Tensioner Systems
- Surface Tree
- Flexible Jumpers
- Controls Umbilical
Wet Tree Systems

**Major Components:**
- Subsea Trees
- Manifolds c/w foundations
- Flowlines
- PLETs
- Well and Flowline Jumpers
- EH Umbilicals
- UTAs
- Flying Leads
- Topsides Controls

**Also needed:**
- XT and TH Tooling
- IWOCS
- ROV Tooling
- Misc. Installation Aids
Field Development Planning Considerations

Dry Tree Applications:
- Suitable to all reservoir geometries but limited in areal size due to drilling constraints.
- Upfront decision required on number of well slots or more complex completion designs.
- Facilities are limited as water depth increases (e.g. TLP up to approximately 1,524 m (5,000 ft), Chevron Big Foot).
- Drilling template set below the host facility and drilling step-out distances limit drilling capabilities.
- Direct vertical flow path from subsurface completion minimizes flow assurance issues.
- Excludes the use of standalone FPSO but host facility can be paired with FSO to allow in field storage.
- Predrill operations require a MODU with completions handled by onboard rig.
- SIMOPS required for drilling and production operations on same facility.
- SIMOPS requires greater level of safety planning. Dropped objects during drilling is a major concern.
- Production ramp up limited by wait for onboard rig for completions.
Field Development Planning Considerations

**Wet Tree Applications:**
- Suitable to all reservoir geometries and areal size.
- Can provide flexibility in number of wells for development.
- Not constrained by current water depths in which industry operates.
- Limited only by seafloor topography. Wells can be located as standalone locations or clustered locations.
- Suitable for infield developments and long distance tie-backs.
- Distance from host facility may result in reduced well performance due to pressure drop and flow assurance issues.
- Supports use of floating facilities with storage capability (FPSO).
- Suitable for predrill or drilling over time (DOT).
- Requires mobile assets for workover/intervention work (MODUs, MSVs, etc.).
- Drilling is segregated from production operations.
- Ability to predrill and complete allows for quick production ramp up once facility is commissioned.
Impacts to Floating Facility Selection- Dry Tree

- Surface Tree, main component for well control, located on production deck.
- Direct vertical access to all or some wells.
- Higher payload due to large number of risers, tensioners and drilling facility.
- Larger deck area required to accommodate well bay.
- Hull selection is limited to SPAR, TLP and Semi (not in use at this time).
- Host (hull) supports risers and drilling facility which require motion optimized hull such as SPAR or TLP.
- With increasing water depth the riser payloads increase and the complexity of the hull and risers design increases.
  - Complex riser design issue - Limited by riser tensioner capacity.
  - Tighter watch circle required to maintain risers within operational performance window.
- Deepest dry tree facility: Devil’s tower, SPAR in 1,710 m (5,610 ft) WD, GoM 2004.
Impacts to Floating Facility Selection- Wet Tree

- Subsea Tree, main component for well control, located at sea bed.
- Fewer number of risers required as flow lines are grouped together subsea.
- Fewer number of risers results in lower payload on hull.
- Greater flexibility in terms of hull selection and future expansion.

- Subsea wet tree systems typically paired with an FPSO but can be used with any hull form.
- Smaller impact on topsides weight, layout and payload requirements.
- Deepest wet tree application is the Perdido development, SPAR with wet tree completion in 2,926 m (9,600 ft) WD (Tobago Field).
Case Study Assumptions

General Field Data:
- Location / Metocean: U.S. GoM
- Water Depth: (1,200 m) 4,000 ft
- Design and Field Life: 25 years
- Reservoir Extent: 15 sq miles / homogenous
- Reservoir Depth: 10,000 ft (3,048 m) TVD below mudline
- SIWHP <10,000 psi
- Maximum Oil Rate: 80 kbopd
- Maximum Gas Rate: 67 mmscfd
- Maximum Liquid (O&W) Rate: 120 kbpd
- Total Wells: 22 wells, 11 production, 11 water injection

Drilling Data:
- 5,500 Mt Onboard Drilling and Completion Unit with DVA
- Drilling & Completion Estimates:
  - Initial Drilling Time: 50 (dry) to 60 (wet) days
  - Initial Completion Time: 48 (dry) to 30 (wet) days
  - Learning Curve Effect: 15% on both drilling and completion
- Onboard rig operating costs is 45% of the MODU rate
- MODU rate assumed at $840k per day

Wet Tree Host Facility:
- Facility Type: SPAR
- Length: 180 m
- Hull Diameter: 39 m
- Operating Draft: 162 m
- Hull Weight: 20,065 Mt
- Displacement: 78,942 Mt
- Drilling Unit: None

Dry Tree Host Facility:
- Facility Type: SPAR
- Length: 186 m
- Hull Diameter: 41 m
- Operating Draft: 167 m
- Hull Weight: 24,209 Mt
- Displacement: 105,568 Mt
- Drilling Unit: 5,500 Mt
Case Study Methodology

• Create reservoir description for case study.
• Develop production profiles and well counts.
• Create development plans for each scenario.
  – Wet tree with SPAR production facility.
  – Dry tree with SPAR drilling and production facility.
• Create EPCI and D&C development schedules.
• Create CAPEX estimates and time phased investment schedules.
• Create OPEX estimates and time phased expense schedules.
• Perform economic modeling.
  – Study effect of differences in D&C on CAPEX, development economics and concept selection.
• Summarize findings.
Case Study Results

Schedule & Production Comparison:

![Production Volumes (boe)](image)
Case Study Results

CAPEX Comparison:

<table>
<thead>
<tr>
<th></th>
<th>Wet Tree Development</th>
<th>Dry Tree Development</th>
<th>Delta $</th>
<th>Delta %</th>
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<tbody>
<tr>
<td>Facilities</td>
<td>$2,034,107</td>
<td>$2,131,164</td>
<td>$97,057</td>
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<td>Installation &amp;</td>
<td>$469,574</td>
<td>$292,371</td>
<td>$177,203</td>
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<td>Commissioning</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Drill &amp; Complete</td>
<td>$3,893,500</td>
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<td><strong>TOTAL:</strong></td>
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<td><strong>$5,355,960</strong></td>
<td><strong>$1,235,335</strong></td>
<td>100%</td>
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</tbody>
</table>

• Facilities differential is driven by the subsea production system cost.
• Installation & Commissioning differential is driven by the subsea production system (flowlines, risers, subsea kit).
• Drill and Completion differential cost is driven by the rig operating costs (MODU rate vs. onboard rig operating rate).
Case Study Results

• Economic Comparison with CAPEX sensitivity:

Discount Rate: 12%
Best estimate CAPEX for Wet Tree: $6.4 B and Dry Tree: $5.4 B
CAPEX sensitivity: +40% / -20%
Conclusions

• Technical considerations, investment levels and economics are all considerations in the dry vs. wet concept selection decision.
• Level of uncertainty in the data plays an important role.
• A comprehensive evaluation methodology needs to be used during concept selection.
• During the concept select and PreFEED phases of engineering definition, selection of either a wet tree or dry tree solution may be premature.
• Concept selection is a time based decision as more definition is achieved.
End of Presentation

• Thank You

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