OFFSHORE FIELD DEVELOPMENT OPTIONS & STRATEGY

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This presentation will not focus on detailed theory and development of equations.

But, the emphasis is on what is being done, why it is being done, what technology exist and how well does it work.

Most of all, how does it relate to the practical decisions.
PRESENTATION CONTENT

- Field Development Consideration
- Field Development Options & Strategy
- Phased Development & Facilities Optimization
THE LIFE CYCLE OF A PETROLEUM RESERVOIR

PROJECT DEFINITION → DISCOVERY → APPRAISAL → DEVELOPMENT PLANNING → ONGOING DEVELOPMENT → PRODUCTION → DEVELOPMENT → DEPLETION → ABANDONMENT
RESERVOIRS & PRODUCTION CONSIDERATIONS

- Reservoir Characteristic
- Completion design
- Rates
- Facilities Design
- Capex Opex
- Production Problems
- Well Spacing

Reserves
NATURE OF HYDROCARBON FIELD

Complexities

- Geological (faulted)
- Reservoir properties ($\Phi$, $K$, $So$, $Sw$)
- Hydrocarbon reserves (reliability & distribution)
- Fluid properties (wax, $H_2S$, $CO_2$, salt, GOR...)
- Reservoir fluid flowing Process
- Well completion (Single selected, dual completion)
DEVELOPMENT OPTIONS & STRATEGY
DEVELOPMENT OPTIONS

Surface Facilities

Well completion

Reservoir Engineering
DEVELOPMENT OPTIONS

Surface Facilities

✓ WHP + FPSO
✓ WHP + CPP + FSO
✓ WHP + CPP + Pipeline to Shore
✓ WHP + Pipeline to Shore + Processing Plant
✓ FPSO:  New built & Conversion
✓ FSO:  New built & Conversion
✓ CPP:  Conventional sub-structure, Jack-up, TLP & Gravity Concrete foundation
✓ WHP + FPSO
✓ WHP + CPP + FSO
✓ WHP + CPP + Pipeline to Shore
✓ WHP + Pipeline to Shore + Processing Plant
PHASE 1 – FIELD DEVELOPMENT PLAN
PHASE 2—FIELD DEVELOPMENT PLAN
PHASE 2 – FIELD DEVELOPMENT PLAN

- Export Tanker
- FPSO
- PLEM
- WHP
- CPP
DEVELOPMENT OPTIONS

Well completion

✓ Subsea Wellhead

✓ Wellhead On Platform

✓ Single, selective or dual completion
FIELD DEVELOPMENT

SCARAB/SAFFRON DEVELOPMENT
GENERAL ARRANGEMENT

- 12" manifolds with 18" jumpers to 15" FLET
- Infield umbilical
- UTA with flying leads
- Horizontal tree
- 16" jumper
- 10" flowlines
- 10" FLET
- Dual 20" Q4/Q5 export pipelines, FLETS and PEM
DEVELOPMENT OPTIONS

Well completion

- Selective Completions

- Single zone at any one time
DEVELOPMENT OPTIONS

Well completion

Multi-zone Completions

- Commingled completions

- Concern if fluid composition different

- high condensate content or sour gas

- Concern if zone pressures are different

- differential depletion & cross flow

- concern about water & break through
DEVELOPMENT OPTIONS

Well completion

*Multi-zone Completions*

- Segregated Tubing & Annulus flow
- Annulus corrosion & erosion
- Liquid unloading from annulus
DEVELOPMENT OPTIONS

Well completion

*Multi-zone Completions*

- Multi-string completions

  - tubing size restricted & capacity limited
  - difficult to work over
  - need good cement jobs
Horizontal completion

✓ Thin reservoir
✓ Low permeability reservoir
DEVELOPMENT OPTIONS

Reservoir Engineering

- Water injection
- Gas injection
- Gaslift, Submersible pump, …
DEVELOPMENT STRATEGY
FIELD DEVELOPMENT

Make decision for:

- Facilities Phasing & Capacities
- Wells number, locations & Completion
- Drilling schedule
DEVELOPMENT STRATEGY

Make decisions in consideration of:

- Down-Side risk & Up-Side potential
- Min reserve & Max reserve
- Variation in Capex, Opex, Price
DEVELOPMENT STRATEGY

Make decisions in consideration of:

Optimization & Maximization

- Optimized production rate & maximized production rate
- Optimized prod. reserve & maximized prod. reserve
- Company’s profit & Government profit
The 3rd Workshop of Cambodia (PPM) Case Study
March 29 – April 3, 2004, Siem Reap, Cambodia

Development Strategy

Make decisions in the face of uncertainties:

1. Geological uncertainties:
   - Hydrocarbon Generation
   - Hydrocarbon Seal
   - Reservoir Rock Properties
   - Hydrocarbon IIP Volumes
   - Reservoir Energy Mechanism
     (aquifer volume? Gas cap volume? GOR?...)

   ✓ Migration Path
   ✓ Reservoir Trap
   ✓ Type of Hydrocarbon
   ✓ Reservoir Fluid Properties
DEVELOPMENT STRATEGY

Make decisions in the face of uncertainties

2. Engineering Uncertainties:

✓ Well Performance – Number of wells
✓ Recovery factor – reserves – Production profile
✓ Facilities Design
✓ Project Start-up (delay in start-up)
DEVELOPMENT STRATEGY

Make decisions in the face of uncertainties

3. Commercial Uncertainties:

- Political
- Markets (oil & gas markets)
- Capex
- Opex
FOCUS OF DEVELOPMENT STRATEGY

- To avoid uneconomic development
- To ensure safety for Person, Environment & Reservoir
- To ensure adequate economic return
- To derive maximum benefit from available data sets
- To improve reservoir recovery
DEVELOPMENT STRATEGY

Emphasis on

- Reduction of uncertainties
- Reduction of influence of uncertainties
- Sub-optimal initial development
- Opportunities for future optimization
DEVELOPMENT MANAGEMENT PRINCIPALS

Project must be broken into phases

- Conceptual
- Feasibility
- Detail Design
- Material Procurement
- Construction & Start-up

Case Study: D14 to THC
Pipeline material & Gas price?
NORMAL FIELD DEVELOPMENT PLAN SCHEME

Discovery
↓
Preliminary Reserves Evaluation
↓
Outline Plan
↓
Appraisal Drilling
↓
Overall Reserves Evaluation
↓
Field Development Plan
↓
Work Design and Executive
↓
Development Drilling & Production
↓
Abandonment
EARLY FIELD DEVELOPMENT PLAN SCHEME

Discovery

Reserves Evaluation For
Early Development Prospect

Outline Plan

Early Development Plan

Early Work Design and Executive

Early Drilling & Production

Appraisal Drilling

Overall Reserves Evaluation

Field Development Plan

Work Design and Executive

Development Drilling & Production

Abandonment
PHASED DEVELOPMENT & FACILITIES OPTIMIZATION
1. Introduction

2. Challenge Analyzing

3. Recommendation
INTRODUCTION

• Discoveries are more complex in structure, divided by regional and local Faults into Blocks

• Reservoir & Fluid properties are difficult to predict

• Information acquired during exploration & appraisal period is not sufficient to plan a full field development

• To minimise uncertainties, fields are developed by phases
CHALLENGES

• How to optimize production and processing facilities for first phase

• Facilities for first phase should be installed with low cost to minimize risk, but flexible to upgrade for future field development and production
FPSO DESIGN OPTIMISATION

- Natural reservoir depletion has low recovery factor, which varies from 13% to about 23% depends on reservoir structures and properties

- Water injection application will increase oil recovery factor up to more than 40%
Key factor allows Contractor to apply water injection in next phase of field development is a number of swivel, pre-designed and installed on FPSO.

Some FPSO has been designed with only one production riser and swivel.

Dry dock for the FPSO to modify turret and install water injection, gas lift facilities, caused production shutdown for long time and big increase of investment.
**Example:** FPSO have been designed with one spare swivel for water injection, could save 42 mm USD.

<table>
<thead>
<tr>
<th>Increased oil production</th>
<th>7 million barrels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No dry dock</td>
</tr>
<tr>
<td>1. Water injection facilities installation</td>
<td>20 mmUSD</td>
</tr>
<tr>
<td>2. Impact of production shutdown</td>
<td>50 mmUSD</td>
</tr>
<tr>
<td>3. Well drilling completion</td>
<td>140 mmUSD</td>
</tr>
<tr>
<td>4. Increased oil production</td>
<td>2 mmUSD</td>
</tr>
<tr>
<td>5. Pre-installed spare swivel</td>
<td></td>
</tr>
</tbody>
</table>
EXTERNAL TURRET MOORING SYSTEM
CROSS-SECTION INTERNAL & EXTERNAL TURRET
Recommendation

- FPSO to be designed with one or more spare swivel for crude oil, water injection or gas lift

- FPSO facilities layout should be considered to reserve space for future facilities installation with minimum modification of existing facilities
IN-FIELD PIPELINE DESIGN OPTIMISATION

- Reservoir fluids produced & transported through infield pipeline usually are mix of fluids from different reservoirs with different physical and chemical properties.

- Reduction in the pipeline flow rate could lead to reduction in fluid temperature and pipeline stack.

- Pipeline reinstalation is costly operation.
INFIELD PIPELINE DESIGN
OPTIMISATION
Wax deposition as a function of temperature

- Well-1
- Well-2
- Well-3
- Well-4
- Well-5
INFIELD PIPELINE DESIGN
OPTIMISATION

Viscosity as a function of temperature

Shear Rate
- 3 1/sec
- 10 1/sec
- 30 1/sec
- 100 1/sec
- 200 1/sec
INFIELD PIPELINE DESIGN OPTIMISATION
Temperature Profile
Conclusions

• Infield pipeline to be designed with carefully consideration of changes in reservoir fluid temperature, crude cloud point and changes of pipeline flow rate during field life

• Infield pipeline to be insulated is strongly practical recommendation.
WHP DESIGN OPTIMISATION

Challenges:

WHP has been designed

- Without shelter for workers to stay overnight on platform
  - *When weather changed to severe condition person life under dangerous*

- With crane of small capacity
  - *Operator have to use rig to do work over*
Challenges:

WHP has been designed

- With one board landing only

✓ In windy and strong current condition, supply board could damage to board landing and risers

✓ Take long time to wait on weather
WELL HEAD PLATFORM (WHP)
Recommendations

- It is recommended to install crane with capacity at least 25 tone on WHP for wireline and coil tubing operation to be done

- Install shelter for workers to stay overnight on platform (four beds)

- Design and construct WHP with two board landing in opposite sides.
CONCLUSIONS

- Design of production, processing facilities, FPSO, WHP and infield pipeline for phase 1 should take into account future field development plan, to allow:

  Facilities expansion and application of water injection & gas lift

- Optimized design results in resource conservation, increase oil & gas recovery factor, and significantly increases national revenue and operator’s benefit
It is recommended

- FPSO to design with one or more spare swivels used for produced fluids, water injection or gas lift
- Reserve space on FPSO for future facilities installation
- Infield pipelines for crude oil transportation is strongly recommended to insulate.
CONCLUSION

It is recommended

• Crane capacity on Well head platform is 25 ton minimum

• Two board landing on WHP

• Shelter with four beds to be installed on WHP
Thank you very much
### Summary of Stock Tank Crude Properties

<table>
<thead>
<tr>
<th>Fluid Property</th>
<th>Well No.</th>
<th>Reservoir (Fingerprinting)</th>
<th>Basement (Base/Mio. Mix)</th>
<th>Basement</th>
<th>Basement</th>
<th>Basement</th>
<th>Basement</th>
<th>Basement</th>
</tr>
</thead>
<tbody>
<tr>
<td>API @ 60 F</td>
<td>15-1-SD-1x</td>
<td>Hydrometer</td>
<td>35.6</td>
<td>37.0</td>
<td>36.0</td>
<td>35.9</td>
<td>35.5</td>
<td></td>
</tr>
<tr>
<td>Specific Gr.</td>
<td>15-1-SD-2x</td>
<td>Hydrometer</td>
<td>0.8468</td>
<td>0.8398</td>
<td>0.8448</td>
<td>0.8453</td>
<td>0.8473</td>
<td></td>
</tr>
<tr>
<td>Cloud Point (WAT)</td>
<td></td>
<td>Polarized Microscopy</td>
<td>67 °C (153°F)</td>
<td>71 °C (160°F)</td>
<td>73 °C (164°F)</td>
<td>68 °C (155°F)</td>
<td>32 °C (89°F)</td>
<td></td>
</tr>
<tr>
<td>Cloud Point (GUTS Model)</td>
<td></td>
<td></td>
<td>69 °C (185°F)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pour Point</td>
<td></td>
<td>ASTM D5853-95</td>
<td>29 °C (85°F)</td>
<td>35 °C (85°F)</td>
<td>38 °C (100°F)</td>
<td>29 °C (85°F)</td>
<td>18 °C (65°F)</td>
<td></td>
</tr>
<tr>
<td>Gel Strength (Pa)</td>
<td></td>
<td></td>
<td>Hasake RS 150 Rheometer</td>
<td>411 Pa @ 22.3°C</td>
<td>338 Pa @ 25.0°C</td>
<td>451 Pa @ 22.1°C</td>
<td>185 Pa @ 22°C</td>
<td></td>
</tr>
<tr>
<td>Dead Crude (22 &amp; 25°C)</td>
<td></td>
<td></td>
<td>Hasake RS 150 Rheometer</td>
<td>338 Pa @ 25.0°C</td>
<td>338 Pa @ 25.0°C</td>
<td>307 Pa @ 25°C</td>
<td>82.4 @ 25°C</td>
<td></td>
</tr>
<tr>
<td>Live Crude (Saturated with 200 psig CH4)</td>
<td></td>
<td></td>
<td>Hasake RS 150 Rheometer</td>
<td>279 @ 21.6</td>
<td>193.4 @ 22.3</td>
<td>121.1 @ 23.7</td>
<td>120.6 @ 21.4</td>
<td></td>
</tr>
<tr>
<td>HTGC</td>
<td></td>
<td></td>
<td>Hasake RS 150 Rheometer</td>
<td>Completed</td>
<td>Completed</td>
<td>Completed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wax Content (wt%)</td>
<td>13.1</td>
<td></td>
<td>16.4</td>
<td>16.5</td>
<td>13.2</td>
<td>9.6</td>
<td></td>
<td></td>
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<tr>
<td>Wax Deposition</td>
<td></td>
<td></td>
<td>Completed</td>
<td>Completed</td>
<td>Completed</td>
<td>Completed</td>
<td></td>
<td></td>
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<tr>
<td>Viscosity (5 Temps 75 to 20 C)</td>
<td></td>
<td></td>
<td>Hasake RS 150 Rheometer</td>
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<td>Completed</td>
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<tr>
<td>Viscosity (Saturated with 200 psig CH4)</td>
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<td>Hasake RS 150 Rheometer</td>
<td>Completed</td>
<td>Completed</td>
<td>Completed</td>
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<tr>
<td>Asphaltene Total</td>
<td>0.47</td>
<td></td>
<td>0.44</td>
<td>0.35</td>
<td>0.24</td>
<td></td>
<td></td>
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<tr>
<td>Asphaltene Titration</td>
<td>Stable</td>
<td></td>
<td>Stable</td>
<td>Stable</td>
<td>Stable</td>
<td>Stable</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**INFIELD PIPELINE DESIGN OPTIMISATION**

Wax deposition model result for WHP to FPSO oil pipeline

<table>
<thead>
<tr>
<th>Flow Rate</th>
<th>Thermal Mass (kJ/s)</th>
<th>Time to Deposit 4 mm Wax on Bare Steel Pipe Wall (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Only 50 mm Concrete Weight Coating 1” of Insulation under 50 mm Concrete Weight Coating</td>
</tr>
<tr>
<td>BOPD</td>
<td>BWPD</td>
<td></td>
</tr>
<tr>
<td>32,000</td>
<td>0</td>
<td>105</td>
</tr>
<tr>
<td>44,000</td>
<td>0</td>
<td>145</td>
</tr>
<tr>
<td>56,000</td>
<td>0</td>
<td>184</td>
</tr>
<tr>
<td>32,000</td>
<td>13,400</td>
<td>209</td>
</tr>
<tr>
<td>44,000</td>
<td>22,000</td>
<td>314</td>
</tr>
<tr>
<td>32,000</td>
<td>32,000</td>
<td>352</td>
</tr>
<tr>
<td>56,000</td>
<td>28,000</td>
<td>400</td>
</tr>
<tr>
<td>44,000</td>
<td>44,000</td>
<td>484</td>
</tr>
<tr>
<td>56,000</td>
<td>56,000</td>
<td>616</td>
</tr>
</tbody>
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