“A New Build Minimal Cost FPSO & FSO Barge Design”
Optimised Solution
Main Drivers & Objectives

Traditionally FPSO projects mostly end up over budget and over schedule!

- Clients are looking for:
  - High quality & fit for purpose
  - Minimum risk
  - Minimum schedule
  - Low cost

- Irvine can supply:
  - Simple, functional and fit for purpose designs
  - Best risk management system - elimination, mitigation, management “No Surprises”
  - Realistic schedules and schedule management – Meet first oil target
  - Procurement management and cost controls – Minimal CAPEX
  - Simple manageable interfaces

Simple, Functional & Minimal Cost Design
Main Features

• Designed for benign deepwater environments
• Innovative midships ballast tanks configuration
• Storage capacity and vessel sizing flexibility
• Spread moored system
• High topsides payload capability and flexibility
• Simple, robust, rectangular mild steel construction
• Minimised interfaces
Design Details and Benefits

- Wide beam/shallower draught/lower mooring loads
- Bending moment reduction from midship ballast tank configuration
- Lower stresses permits wide use of mild steel
- Low yield strength steel reduces fatigue problems
- Increased safety factors employed to give up to 15% increase in fatigue life

Zero Based Design
Design Details and Benefits cont’d

• Single centreline bulkhead
• Narrow wing ballast tanks/Damage condition heel angle small
• Natural period (12 to 13 secs) tuned to below regional swell period
• Battered ends/reduced buoyancy
• Capacity range of 150,000 m³ to 400,000 m³
• Range of design between 6 and 16 tanks

Zero Based Design
Design Details and Benefits cont’d

- No turret interface
- Scope split based on skill base
- Marine equipment largely above deck
- Large topsides modules with functional splits
- Module installation flexibility
BARTOP Base Design Description

- Dimensions: Length = 250.5m, Breadth = 69.7m, Depth = 25.5m, Draught = 19.0m
- Rectangular purpose designed production barge
- Spread moored using 16 mooring lines
- 12 Cargo Tanks
- 300,000 m³ storage (1.86 M barrels)
- Double side hull structure
- Designed topsides payload of 32,000 tonnes
BARTOP Sizing Flexibility

The hull consists of robust standard tank sections

Storage capacity can be changed without having to re-engineer the entire design

Flexibility to Change Capacity
## BARTOP Capacities

### BARTOP-300 Design Range - Full Load Equilibrium and Weights Summary

<table>
<thead>
<tr>
<th>Tanks</th>
<th>Cargo Oil Capacity (m³)</th>
<th>LBP (m)</th>
<th>Trim (m)*</th>
<th>Draught (m)</th>
<th>Lightship weight (te)</th>
<th>Topsides weight (te)</th>
<th>Displacement t (te)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 Tanks + B</td>
<td>396,500</td>
<td>319.5</td>
<td>0.63</td>
<td>19.8</td>
<td>49,500</td>
<td>42,500</td>
<td>434,388</td>
</tr>
<tr>
<td>12 Tanks + B</td>
<td>295,500</td>
<td>256.5</td>
<td>0.79</td>
<td>19.0</td>
<td>39,650</td>
<td>32,000</td>
<td>329,755</td>
</tr>
<tr>
<td>10 Tanks</td>
<td>245,000</td>
<td>207.0</td>
<td>0.75</td>
<td>19.7</td>
<td>32,000</td>
<td>24,000</td>
<td>271,994</td>
</tr>
<tr>
<td>8 Tanks + B</td>
<td>194,500</td>
<td>193.5</td>
<td>1.07</td>
<td>17.7</td>
<td>30,000</td>
<td>22,000</td>
<td>225,822</td>
</tr>
<tr>
<td>8 Tanks</td>
<td>194,500</td>
<td>175.5</td>
<td>0.66</td>
<td>19.7</td>
<td>27,250</td>
<td>19,000</td>
<td>220,072</td>
</tr>
<tr>
<td>6 Tanks</td>
<td>144,000</td>
<td>144.0</td>
<td>2.42</td>
<td>18.2</td>
<td>22,250</td>
<td>14,000</td>
<td>167,930</td>
</tr>
</tbody>
</table>

*Note: All trim is by the stern*
# BARTOP Bending Moment Details

## Shear Force and Bending Moment Comparison

<table>
<thead>
<tr>
<th>Tanks</th>
<th>Max Bending Moment* (te.m)</th>
<th>Distance forward of AP (m)</th>
<th>Max Shear Force (te)</th>
<th>Distance forward of AP (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 Tanks + B</td>
<td>539,105</td>
<td>70.0</td>
<td>16,909</td>
<td>168.0</td>
</tr>
<tr>
<td>8 Tanks</td>
<td>777,794</td>
<td>88.0</td>
<td>18,937</td>
<td>150.0</td>
</tr>
</tbody>
</table>

*Note: All bending moments are sagging moments*
BARTOP Bending Moment Details

Bending Moment Curves

Shear Force

12T + B
10T
8T + B
8T
6T
6T + B

X fwd AP (m)

Shear Force (tonnes)
BARTOP Bending Moment Details

Bending Moment Curves

Bending Moment (tonne.m) vs X fwd AP (m)

-1400000 -1200000 -1000000 -800000 -600000 -400000 -200000 0
0 20.0 40.0 60.0 80.0 100.0 120.0 140.0 160.0
0 -200000 -400000 -600000 -800000 -1000000 -1200000 -1400000

-10T -12T + B -8T + B -8T -6T -16T + B
BARTOP Hull Construction

- Hull form and structure optimised for shipyard construction
- 100% stiffened flat panel construction for fully automated panel line fabrication
- Dry dock erection
- Long lead marine equipment (e.g. generators) placed on deck allowing early start of fabrication and late delivery of equipment
• High margin on topsides payload carrying capacity
• Flexible and robust topsides support arrangements
• Wide deck area to allow improved topsides layouts
• Conservative hull steel scantlings to allow for fatigue and future changes
• Low yield strength steel used for main structure
Shipyard Scope of Work

• Hull

• Marine systems segregated from topsides systems
  minimising interfaces and allowing shipyard commissioning

• Helideck

Other options for yard SoW:

• Accommodation

• Cranes
Main Marine Systems

- Marine control system
- Ballast and bilge systems
- Cargo pumping and export systems
- Diesel fuel system
- Inert gas, tank washing and tank heating systems
- Utilities systems
- Essential and emergency power supplies
- Helifuel system
Marine Systems Locations

AFT MACHINERY SPACE INCORPORATES:
- CARGO EXPORT PUMPS 3x50%
- BALLAST PUMPS 2x50%
- INERT GAS GENERATOR 2x100%
- SELF CONTAINED HVAC SYSTEMS
- ELECTRICAL SWITCH ROOM
- VCS

SLOPS TANK
SEA WATER LIFT PUMP CAISSONS

BARTOP 300 MARINE SYSTEMS

FORWARD (Vessel North)

FIRE PUMPS (Typical port and starboard sides)

VESSEL SCOPE TO INCLUDE:
- MODULE SUPPORT FRAMES
- EGRESS TUNNELS (excluding local sections to modules)
- AFT CRANE
- LOWER PEDESTAL SECTIONS (for both forward and mid sections)
- HOSE SUPPORT STRUCTURE AND

VESSEL FEATURES:
* STANDARD MARINE SYSTEMS *
* MINIMUM SYSTEMS INBUILT *
Transverse Web Frame Section

GENERAL NOTES
FRAME SPACING = 4000
MATERIAL = MILD STEEL CLASS I

0
Hull Engineering Strategy

- Develop from Irvine standard design
- Hull design team part of the Project Management Team (PMT)
- Irvine develops vessel and main system concepts, carries out model tests and FE / fatigue analysis and prepares key specifications
- Design developed by Irvine to achieve classification society main scantling approval
- Key shipyard engineers to work with hull engineering team for design handover
- Shipyard to prepare fabrication drawings and detailed layouts with Irvine support
## Comparative Vessel Motions

### 100 Year Wave Condition

<table>
<thead>
<tr>
<th>100 Year Wave</th>
<th>Motions / Degrees / Metres</th>
<th>Accelerations (Fwd, beam &amp; upper deck)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Roll</td>
<td>Pitch</td>
</tr>
<tr>
<td><strong>BARTOP 300</strong> (West Africa)</td>
<td>7.0</td>
<td>2.2</td>
</tr>
<tr>
<td><strong>Terra Nova</strong> (Newfoundland)</td>
<td>8.9</td>
<td>4.7</td>
</tr>
</tbody>
</table>

100 year wave condition comparison - BARTOP and Terra Nova FPSO
Current Status of Design

- Design basis documentation completed
- Hull sizing completed
- Motion analysis completed
- Intact and damage stability analysis completed
- Marine systems flow diagrams completed
- Preliminary hull structural design completed including midships cross section, bulkheads and web frames
- Mooring system design part completed
Other Design Work Part Completed

• Sloshing loads
• Fatigue analysis
• Topsides supports
• F E Strength analysis
• Green water
• Model Testing
• Fwd / Aft structure
• Mooring and other attachments
Moorings Arrangement Options

- Passive mooring system
- Spread moored
- Taut mooring lines

Taut Mooring Line

Passive Mooring Line

Tensioner locking device
Chain jack

Mooring line
Fairlead

Drag Anchor or Suction Anchor
Typical Mooring Line Arrangement

<table>
<thead>
<tr>
<th>Line Section</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Chain</td>
</tr>
<tr>
<td>2</td>
<td>Spiral Strand</td>
</tr>
<tr>
<td>3</td>
<td>Chain</td>
</tr>
</tbody>
</table>

Passive mooring line arrangement example
Example Deep Water Riser Options

- **Taut Mooring Line Option**
- **Suction Anchor**
- **Drag Anchor or Suction Anchor**

- **Passive Mooring Line Option**
- **Flexible Risers**
- **Mid Water Buoy**
- **Steel Vertical Riser**
Mooring System Description

- Increased barge width yields 17% reduction in mooring loads
- Spread moored using 16 combination chain / wire or polyester mooring lines
- Passive hydraulic system with 4 chain jacks and 16 chain stoppers
- 16 Dismountable fairleads
- 16 Suction anchors
- 2 Hydraulic power packs
- 1 Line load monitoring system
Production Capability

- OIL: 200,000 BOPD
- GOR: 500 - 1500 SCF/BBL
- GAS INJ: 180 MMSCFD
- GAS EXPORT: 190 MMSCFD
- WATER INJ: 300,000 BWPD
Topsides Engineering Strategy

• Engineering key to a robust concept development
• Conceptual design / feed phase for all elements (hull, topsides and moorings)
• Utilise FPSO specialist personnel from Irvine
• Other project participants co-located in design office from start of project contributing to engineering solutions, including:
  – Fabricators
  – Key system and package suppliers
  – Commissioning
  – Operations
• Maximise topsides system segregation from hull systems to minimise interfaces
• Internal engineering interfaces and data management key Irvine focus
• External engineering interfaces and data transfer
Topsides Layout

Piping Hook-up Scope

Minimal Hook-ups!
Execution Plan Options Overview

- Project management - Project Office
- Topsides engineering - Project Office
- Hull engineering - Project Office
- Moorings engineering - Project Office

Barge & topsides fabrication, construction & Integration options

Moorings suppliers

Europe

Korea

China

Singapore
Essential Route to FPSO Completion

- Integrated HUC / Operations Team
- Minimum Vessel to Topsides Hook-Up
- Minimum module to module Hook-Up
- Maximise Onshore Commissioning
- Minimise Integration Yard Hook-Up
- Minimise Integration Yard Commissioning
All Stakeholders Need to Participate

1. Kick off meeting - start process
2. Each package develops its own register
3. Identify initial delivery dates
4. IDC issues to all packages in Interface Registers
5. Register finalisation meeting
   - agree delivery dates
   - resolve register conflicts
6. Interface Registers maintained and updated by each package
7. Interface Registers issued for use

Interface Register Set-up Process

All Stakeholders Need to Participate
Hull & Topsides Integration Philosophy

Interface Management

- DRILLING
- RESERVOIR
- SUBSEA
- INSTALLATION
- FLOWLINES/RISERS

CLIENT

CONTRACTOR

OPERATIONS & MAINTENANCE

HULL  TOPSIDES  MOORINGS
Guiding Principals

• Define interfaces as early as possible

• Complete engineering early

• Complete module fabrication with NO outstanding punch list

• Minimize/simplify the interfaces of ALL major components (especially after the placement of hull order)

• Manage proactively rather than reactively (especially after the placement of hull order)

• Manage the interface with a realistic sized team and budget

• Develop contingency plan to compensate for unforeseen events

• Enroll fabricators/contractors
Fundamental Characteristics

- Topsides arranged into minimum number of modules for maximum quayside completion and minimum module/module hook-up on vessel
- Simple barge shaped vessel with no complicated in-built systems for easy construction
- Topsides/vessel configured for trailer loadout of modules onto vessel
- Maximum segregation of topsides and vessel systems
- Vessel builders scope strictly limited to core competency
- Irvine to provide managerial/technical support to achieve particular FPSO technical/quality standards
Example Topsides Layout

- **Non-Modular Equipment**: 1321 te (Gross)
- **Forward (Vessel North)**
- **Aft Machinery Space**
- **Riser Balcony**
- **Power Generation**: 2782 te (Gross)
- **Utilities Module**: 2332 te (Gross)
- **Process Module**: 6030 te (Gross)
- **Flare**: 556 te (Gross)
- **Total Gross Topsides Weight**: 13021 te
Modules Installation

Modules Skidded or Trailered onto Deck

Barge or Quayside

Loading Direction from Barge

Barge
Module Installation at Quayside or Offshore

Installation of topsides packages onto vessel at fabrication yard:

- Topsides installed onto vessel in large modules by skidding or trailer load out from barge
- Topsides modules installed using crane
Module Installation Displaying Supports & Module Support Road

- Module
- Transport Barge
- Trailer
- Bridge Link
- Jacking Points
- Openings

Barge FPSO ready to take onboard modules
High Level Schedule Example
Summary

Design Status:
• FPSO technical definition complete (hull and typical topsides)
• Low cost shipyards identified
• Topsides fabrication yards identified
• Shipyards visited by Irvine management/technical team
• Indicative Vessel prices and schedules received from Shipbuilders
• Reduced complexity between hull and topsides

Expectations:
• Solution is commercially attractive and will achieve a good schedule
• Execution plan developed to mitigate risk of cost escalation and schedule delay
Why BARTOP & Irvine Engineering?

**Irvine Design**
- Improved layouts / Integrated solution.
- Long lead items do not affect hull schedule.
- Simple and robust hull less sensitive to topsides changes.
- Shorter/Beamier hull, efficient ballast design giving reduced mooring loads and offsets.
- Better damage stability characteristics.
- In-house control of design.
- Hand-over period with shipyard
- New fabrication drawings and CNC programmes.

**Shipyard Converted Tanker Design**
- Some fabrication drawings can be used “as is”.
- Shipyard familiar with their own design.
- Schedule benefit (perceived ?).
- A significant amount of re-engineering required.
- Difficult to accommodate late changes and late delivery of long lead packages.
- Longer hull, larger mooring loads and greater offsets.
- Reduced control of design.
- Non optimum solution.
“A New Build Minimal Cost FPSO & FSO Barge Design”

Thank You
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