Emerging FPSO forum

FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

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FPSO Functionality, Risk and Availability

- **FPSO’s provide similar functionality as existing FPS systems in GoM plus storage and offloading facilities which allow direct export to both local and foreign markets [...except dry trees and drilling]**

- **Risks associated with FPSO systems are no greater than for existing platforms: TLP, Spar, Semi [results of 2001 MMS CRA Study]**

- **One could argue that FPSO based systems have higher ‘availability’ than FPS+Pipeline based systems.**
  - If FPSO process facilities or production well has a fault, reserve storage can still be delivered to a shuttle tanker
  - If FPSO shuttle tankers are late or WOW, production can continue when excess storage capacity is available
  - If an FPS or well or pipeline has a fault, delivery to export line stops.
Turret Systems: Elegant Solution, Highly Functional

Provides Station Keeping
- primary method for station keeping (thruster assist can be added)
- restricts offsets to maintain riser system integrity

Allows 360 degree weathervaning capability
- reduces loads on mooring system
- reduces motions for riser system and process (roll)
- passive system can be unmanned during hurricanes

Platform for mooring and riser systems pull-in equipment
- Self contained pull-in systems require no additional support vessels after anchor leg/riser handoff to FPSO
Turret Systems: Elegant Solution, Highly Functional

Provides product transfer system
- Accommodates liquid and gas swivels and pig launching/receiving
- Turret manifold system can replace or augment subsea manifolding

Includes well safety, control and maintenance systems
- Contains emergency shutdown valves/controls
- Wellhead control umbilicals (electric/hydraulic/fiber optic)
- Gas lift and water injection for low pressure formations
- Chemical injection for wax/hydrate control
- Provides spare risers for well testing and round trip pigging
Post-Installation Drilling & Workover NOT in Close Proximity to FPSO Production Operations
Turret Systems: Elegant Solution, Highly Functional
Can add drilling and work-over operations

- Specialized turret design allows simultaneous drilling, production and storage: FPDSO. Non-conventional vessel, conventional components.
Internal Vs. External Turret Systems

External Cantilevered Turret Systems

⇒ Applications in mild to moderate environments:
    West Africa, Southeast Asia, Middle East, South Pacific

⇒ Permanent systems (generally)

⇒ Smaller number of risers

⇒ Shallow to deep water depth applications

*Generally less costly than internal turrets, but not ideal for deep water Gulf of Mexico*
External Turret Mooring Systems
17 Installed, 3 under Construction
Existing External Turret Mooring System in Gulf of Mexico

PEMEX Campeche Bay FSO: 1998, MODEC Intl LLC
Internal Vs. External Turret Systems

Internal Turret Systems

⇒ Applications in moderate to harsh environments:
  Brazil, North Sea, North Atlantic, South China Sea, Gulf of Mexico

⇒ Large number of risers (generally)

⇒ Moderate to deep water applications

⇒ Permanent and disconnectable systems
Internal Turret Systems: Permanent or Disconnectable

- JHN Lufeng 13-1, China
- Petrobras - Albacora, Brazil
- PetroCanada - Terra Nova Newfoundland, Canada
- Petrobras - Barracuda, Brazil
- Amoco Liuhua, China
**5 Disconnectable Internal Turret Systems:**

- **JHN Lufeng, South China Sea**
  - 30+ disconnects since 1994

- **Santos Mutineer-Exeter, NW Australia**
  - 11 disconnects since 2006

- **Petró-Canada Terra Nova, Eastern Canada**
  - 1 disconnect in 2006

- **BHPB Stybarrow, NW Australia**
  - 3 disconnects since 2008

- **BHPB Pyrenees, NW Australia**
  - 2009
Permanent Vs. Disconnectable Internal Turret Systems

Which is the best solution?

- Either approach could be acceptable depending on:
  - Regulatory requirements
  - Owner Company’s approach to Risk
  - Environment

- Each approach has different:
  - CAPEX
  - OPEX
  - Availability
  - Risks
Permanent Vs. Disconnectable Turret Systems

Permanent Turret Systems

⇒ Higher production up-time: don’t necessarily shutdown because of hurricane “threat”, only if direct hit is imminent

⇒ Evacuation decision based on operator preference, not environment

⇒ Lower long-term OPEX

⇒ Less complex mechanical systems

⇒ Must withstand 100-yr hurricane environment
Typical Permanent Internal Turret System

Barracuda FPSO: Campos Basin
834m (2,700ft), 34 Risers

- Swivel Stack (Product/Lift/Controls)
- Manifolds + Pig Launching/Receiving
- Emergency Shutdown Valves
- Anchor Leg + Riser Pull-In Equipment
- Bearing (only upper in this case)
- Turret Shaft / Riser Guide Tubes
- Chain Table (Hawse Pipes/Chain Supports)
- 6 Anchor Legs + 34 Risers
Permanent Vs. Disconnectable Turret Systems

Disconnectable Turret Systems

⇒ Potentially lower risk of hurricane damage
⇒ Decision to shutdown can be delayed, early return to production
⇒ Requires full time marine certified crew and maintenance of self propulsion system
⇒ More complex fluid transfer system and control / instrumentation for disconnect / reconnect
⇒ Not necessarily lower CAPEX than permanent turret system: depends on number of risers, required disconnect/reconnect times, safety features, etc.
⇒ Number of risers can be a limiting factor compared to permanent turret
Disconnectable Turret Systems

JHN Lufeng 13-1, South China Sea:
1 Riser
Less CAPEX than Permanent

PetroCanada - Terra Nova, Newfoundland, Canada:
19 Risers with QCDC’s
More CAPEX than Permanent
Mooring and Riser System Design

Shallow water design
- Vessel offsets = 30% to 40% of water depth: riser design challenge
- Riser loads nearly insignificant for turret design
- Anchor leg / riser interference is key design issue

Deep water design
- Offsets = 10% to 20% of water depth: helps simplify riser design
- Riser loads significant for turret design and total restoring force
- Surge-drift damping contribution from anchor legs and risers is large
- Current loads on anchor legs and risers can be large
- VIV induced motions/loads on risers must be considered for fatigue

\[ \therefore \text{Coupled analysis of mooring \\ & risers is critical for deepwater} \]
Comparison of FPSO Motions to Existing Platforms in the Gulf of Mexico

- Comparison of Maximum Total Heave, Pitch, Vert. Accel.

![Bar Chart showing comparisons of motions for different platforms.](chart.png)

- Maximum Total Heave
- Maximum Total Pitch
- Maximum Vertical Acceleration

**Platforms and Specifications:**
- **FPSO:**
  - 150kDWT, 1MBBL
  - 280kDWT, 2MBBL
- **Semi:**
  - Catenary Risers
- **TLP Spar:**
  - 16 Vertical, 18 SCR's

Non-FPSO Motions courtesy Shell and Deepstar
Semi, Spar and TLP motions are “De-Tuned” from Waves (small waterplane area hull forms compared to FPSO)
- Wave Periods: 4 to 20 seconds (95% energy)
- Semi-Sub Natural Periods: 20 to 50 seconds (heave & pitch)
- Spar/TLP Natural Periods: 30 to 150 seconds (heave & pitch)
- Therefore dynamics are generally less severe than for FPSO

Heave & Pitch Natural Periods for tanker: 8 to 12 seconds

In GOM, FPSO will likely require a more “compliant” or “de-coupled” riser configuration compared to simple catenary or top tensioned vertical risers
FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- Steel Lazy Wave Riser (compliant)

**Inverted Catenary Anchor Leg:**
- 30m 4.00” studless chain
- 300m 4.375” spiral strand wire
- 45 t subsea buoy
- 1,300m 4.375” spiral strand wire
- 900m 5.00” studless chain

**10” Oil Steel Lazy-Wave Riser**

**10” Oil Flexible Lazy-Wave Riser**
Typical Deepwater GoM FPSO Mooring & Riser System

- 3x3 Inverted Catenary Chain & Wire Mooring and Steel Lazy Wave Riser
TLR
Riser
System

Steel Lines
De-Coupled
from
FPSO
Motions
FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

TLR Riser System

Steel Lines De-Coupled from FPSO Motions

Drastically Reduces Turret Loads

SOFEC
**TLR Riser System:**

- FPSO motions de-coupled using a submerged steel buoy supporting SCRs and flexible jumpers to the turret
- Can accommodate a large number of risers
- De-coupling effective \( \Rightarrow \) buoy motions are small
- SCRs’s not affected by the 100-year hurricane or fatigue environments
- Proven technology, with standard fabrication/installation procedures
- DeepStar study concluded that TLR system is feasible in 3,000m depth and less costly than Steel Lazy Wave or Hybrid Riser Towers:

<table>
<thead>
<tr>
<th>COST COMPARISON:</th>
<th>TLR</th>
<th>100%</th>
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<tbody>
<tr>
<td>(based on large, multi-riser field development)</td>
<td>Lazy Wave</td>
<td>120%</td>
</tr>
<tr>
<td></td>
<td>Hybrid Tower</td>
<td>145%</td>
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FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

TLR Riser System

Steel Lines De-Coupled from FPSO Motions
Flowline Termination Buoy (FTB) Riser System

Steel Lines De-Coupled from FPSO

FTB is more robust & fatigue resistant compared to “direct-connect” riser systems
FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

SPM to FTB Riser System

Steel Lines De-Coupled from FPSO

SPM can be CALM or FPSO

SOFEC
SPM to FTB Riser System

Steel Lines De-Coupled from FPSO

Fluid Swivels Above Water
FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

SPM to FTB Riser System

Steel Lines De-Coupled from FPSO

Product Swivels Above Water

SOFEC
Typical Deepwater GoM FPSO Mooring & Riser System

- 3x3 Taut Polyester Mooring and TLR Riser

600 m
Likely Characteristics of the “First” FPSO for the US Gulf:

*(my predictions from 2000 ABS workshop)*

- Large depth because of vast pipeline infrastructure in shallower water
  - 2011 Petrobras Cascade/Chinook FPSO (field discovered 2002): 2,600 meters
- > 1,000,000 bbl capacity: large field more economic in deep water
  - P'Bras Cascade/Chinook FPSO: 600,000bbl (80,000bopd)
- Internal turret because of large number of risers and extreme harsh environment
  - P'Bras Cascade/Chinook FPSO: internal turret, 5 riser jumpers + 4 umbilicals
- Permanent system most economic for many risers / large field
  - P'Bras Cascade/Chinook FPSO: disconnectable (regulatory/operator preference?)
- Taut polyester anchor legs: rapidly gaining acceptance (e.g., Brazil)
  - P'Bras Cascade/Chinook FPSO: polyester moorings
- Extensive use of steel pipe-in-pipe in riser system: presently the norm in GoM
  - P'Bras Cascade/Chinook FPSO: FSHR (P-I-P) + flexible jumpers
- Riser configuration that de-couples steel pipe from vessel wave-freq motions
  - P'Bras Cascade/Chinook FPSO: FSHR + flexible jumpers