

FPSO Riser & Mooring Systems

Ian Frazer

FPSO Training Course
Paris, December 06 – 09, 2016

Overview

- ☐ Introduction
- ☐ Floating Production Systems
- ☐ Anchoring & Mooring Systems
- ☐ Riser Systems
- ☐ Summary and Conclusions

Durward/Dauntless – North Sea

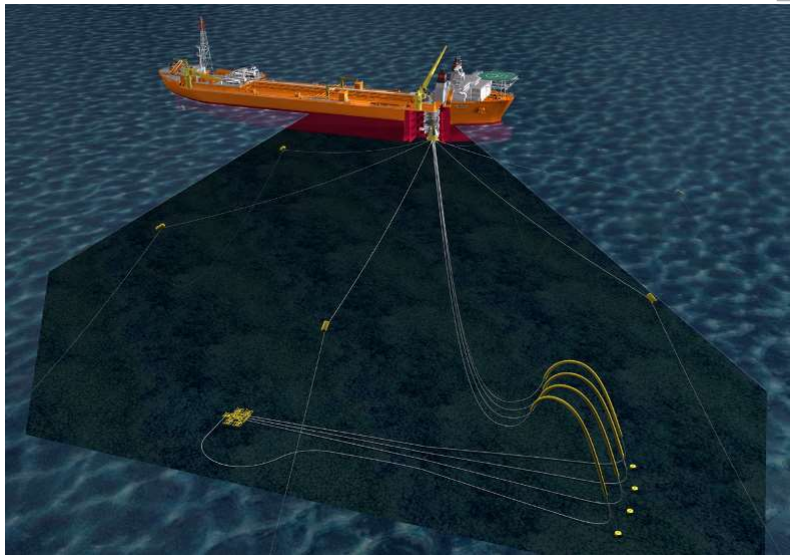


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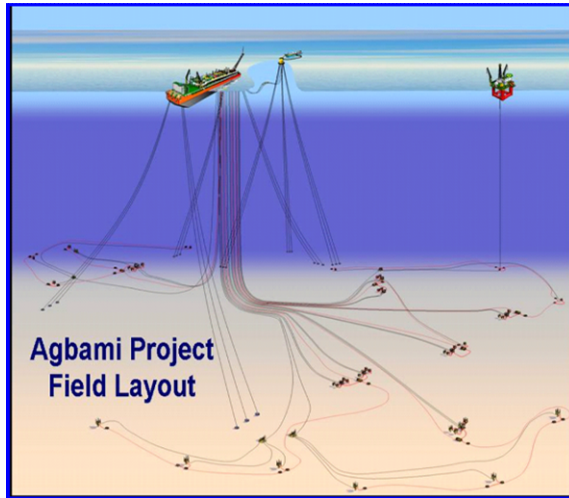
Lufeng Field – China



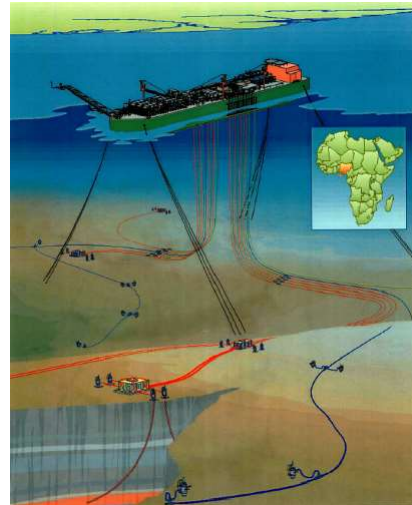
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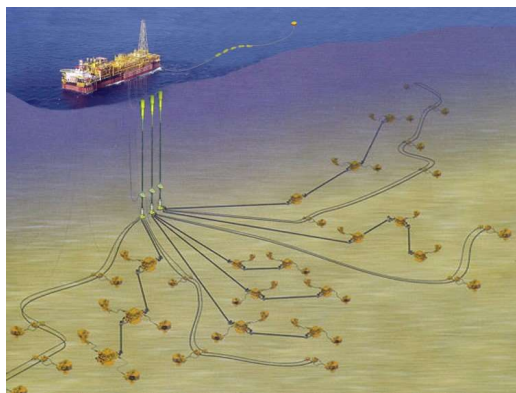


Shell Nigeria Bonga



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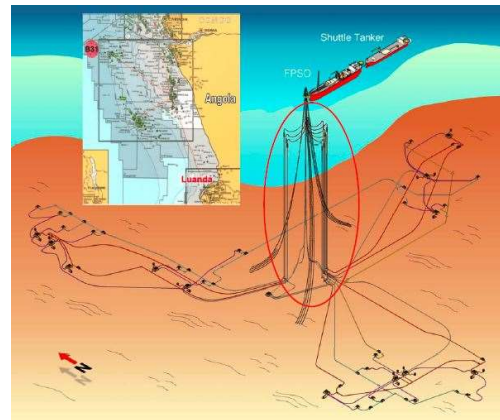
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Girassol - Total



PSVM - BP

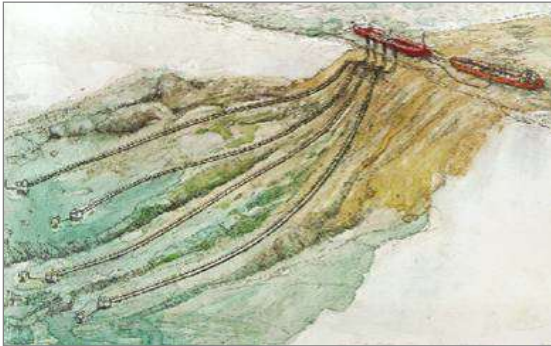


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La Ceiba Project – Equatorial Guinea



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Anchor and Mooring Systems



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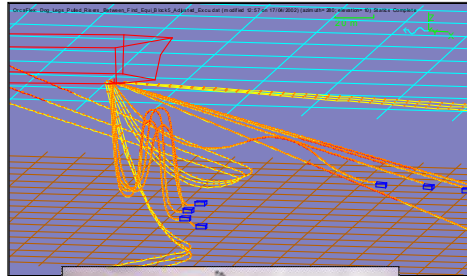
8



Mooring System Function



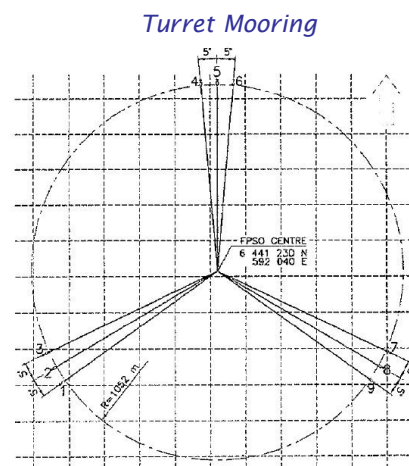
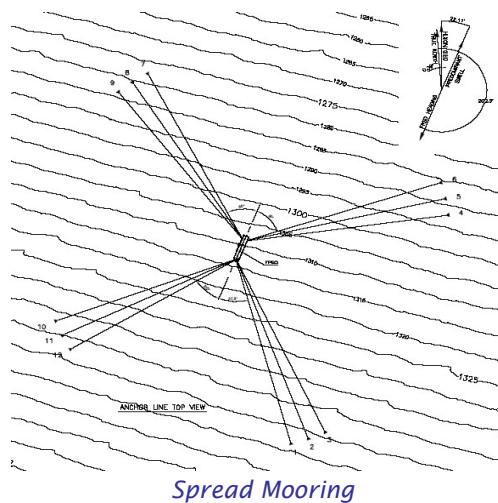
- ❑ Contain FPSO excursions within riser limits
- ❑ Preserve hydrocarbon containment - avoid progressive line, riser & subsea infrastructure damage
- ❑ Accommodate roll, pitch, yaw, heave, surge and sway in **100 year return survival conditions**



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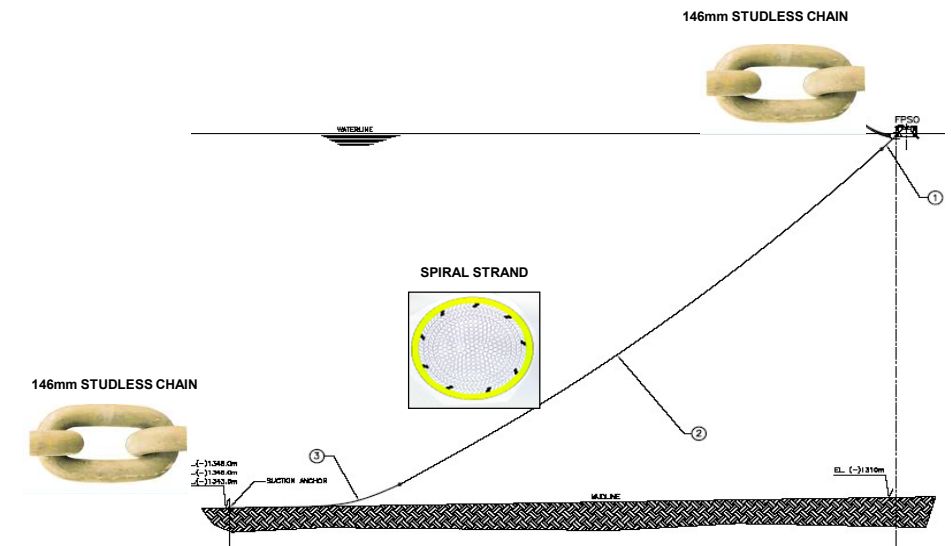
Mooring Systems



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FPSO Mooring Line Profile

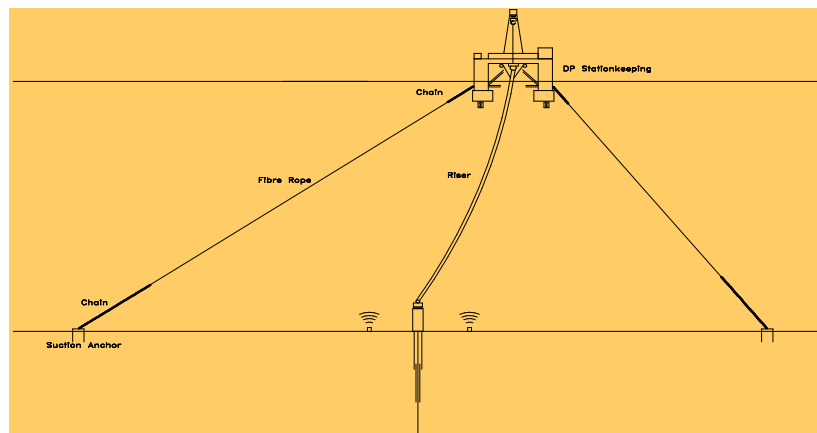


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Taut Leg Mooring System



- Reduced excursions or offsets
- Reduced mooring radius
- Vertical loads on anchors

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Drag Anchors



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Plate Anchors



*SEPLA – Suction Embedment
Plate Anchor*



Intermoor

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Pile Anchors



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Torpedo Pile Anchors



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Suction Anchors



Anchor Selection

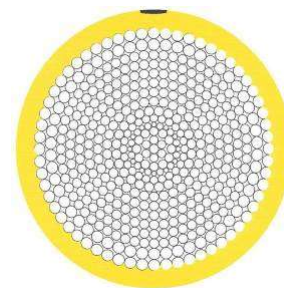
Anchor selection based on :-

- ☐ Seabed soil conditions
- ☐ Mooring loads
- ☐ Mooring system design
- ☐ Water depth
- ☐ Installation equipment
- ☐ Field life
- ☐ Operator preference
- ☐ Cost

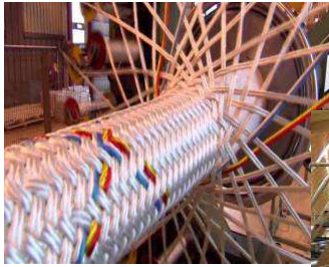
Mooring Chain



Spiral Strand Wire



Synthetic Fibre Rope



Interface with Chain



- ☐ Light weight
- ☐ Polyester
- ☐ Aramid
- ☐ HMPE - Dyneema

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Mooring System Design and Analysis (1)



- ☐ Definition Engineering:
 - Basis of Design approved by all parties including Class Society
 - Geotechnical Surveys and Soils Assessment Verification
 - Met-ocean Data For Location
- ☐ Detail Engineering:
 - Develop Design Premise
 - Calibrate Analytical Models
 - Integrate Riser and Mooring System
 - Model Tests / Cross Check On Analysis
 - Quasi-dynamic Mooring Analysis - Full Draft Range
 - Screening Analysis to Identify Critical Load Cases
 - Dynamic Analysis
 - Fatigue Analysis
 - Mooring analysis for Riser Pull-in
 - Installation Mooring Analysis
 - Mooring/Riser Interference
 - Offloading
- ☐ Class Approval / Independent design review fairly early on – highly recommended

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Mooring System Design and Analysis (2)

- ❑ Assessment Criteria:-
 - Excursions
 - Maximum Tensions
 - Performance with one line or more failed

Shuttle Tanker Alongside Mooring

- ❑ Another variation on the mooring analysis theme
- ❑ Multi body analysis where motion can be out of phase between the two bodies
- ❑ Inevitably relatively short lines between the two floating bodies
- ❑ Therefore limited compliance & mooring loads can shoot up even with only moderate motions in relatively low seas



(Image courtesy of Bluewater)

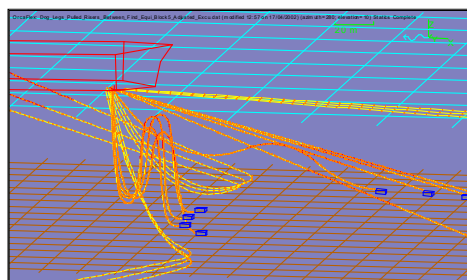
Indicative Max Tension Safety Factors

	API RP 2SK	POSMOOR
Intact: Quasi-Static	2.00	1.70
Intact: Dynamic	1.67	1.50
1 line broken: Quasi-static	1.43	1.10
1 line broken: Dynamic	1.25	1.10

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Typical Riser Excursion Limits

Intact Condition	10% of Water Depth
Damaged Condition	15% of Water Depth



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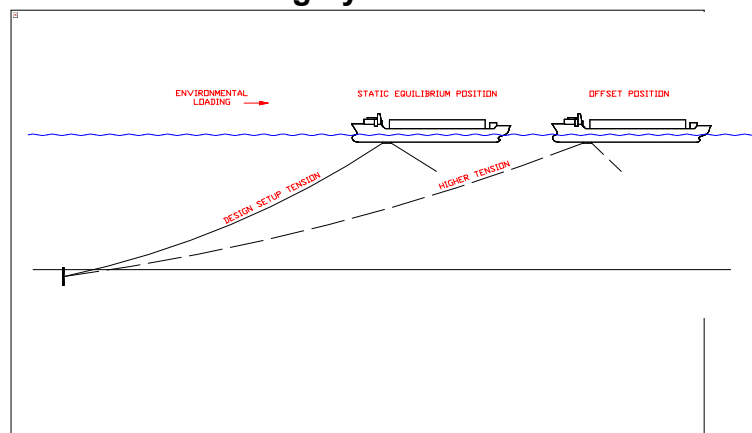
Mooring Analysis

- ☐ Environment Combinations
- ☐ Collinear case
- ☐ Non-collinear case (wind shifted of 15° from wave and current – offshore experience suggests may not always be enough!)
- ☐ Steep wave (maximum slow drift excursion)

- ☐ Environmental loads – Mean or steady force
- ☐ Wave drift force
- ☐ Current forces
 - on vessel
 - on risers
 - on mooring lines
- ☐ Wind forces

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Mooring System Behaviour



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Mooring System – Extreme Conditions



Recordings from weather buoy:
 Significant wave height: 55 ft / 16.8 m
 Maximum wave height: 95 ft / 29.0 m
 Wind speed: 95 knots



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Metoccean Conditions



		West Africa	Gulf of Mexico	West of Shetland
Waves	H_s [m]	3.62	12.2	17.3
	T_p [s]	15.9	14.2	17.9
Wind 1 Hour Average	[m/s]	16.1	36.5	38.4
Surface Current	[m/s]	1.00	1.75	2.00

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Mooring Loads from Model testing

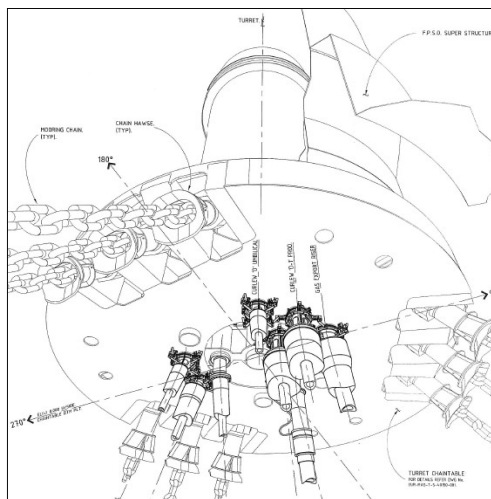


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Turret View from Subsea – Risers + Chains



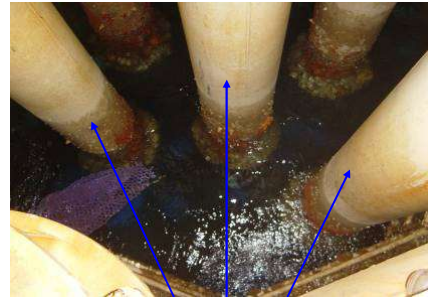
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INSIDE A LARGE DIAMETER TURRET



Base of turret double
Chain stopper/ trumpet
assembly



Risers inside
steel caissons



Dynamic Positioning



- ❑ Dispense with moorings & have full Dynamic Positioning (DP) – but reliability, CO₂ & fuel cost
- ❑ Moorings may be assisted by thrusters – additional contingency & helpful for offloading operations



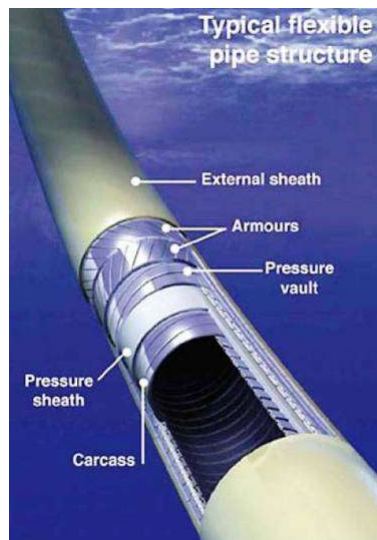
Riser Systems

Riser Systems

- ☐ Extension of flowline system need to be designed for :-
 - Flow rate
 - Pressure
 - Temperature
- ☐ Risers are a critical area for deep and ultra deep water applications
- ☐ Increasing water depth has effect on feasibility of riser systems
- ☐ Three basic riser systems available :-
 - Flexible Risers
 - Steel Catenary Risers
 - Hybrid Risers

Flexible Risers

Flexible Pipe Structure



Flexible Risers



- ❑ Layer pipe structure
- ❑ Factory manufactured
- ❑ 3 main suppliers of Flexible Pipe
 - Technip
 - National Oilwell Varco (NKT Flexibles)
 - GE Oil & Gas (Wellstream)
- ❑ Limited number of factories around world
 - Europe
 - Brazil
 - Malaysia



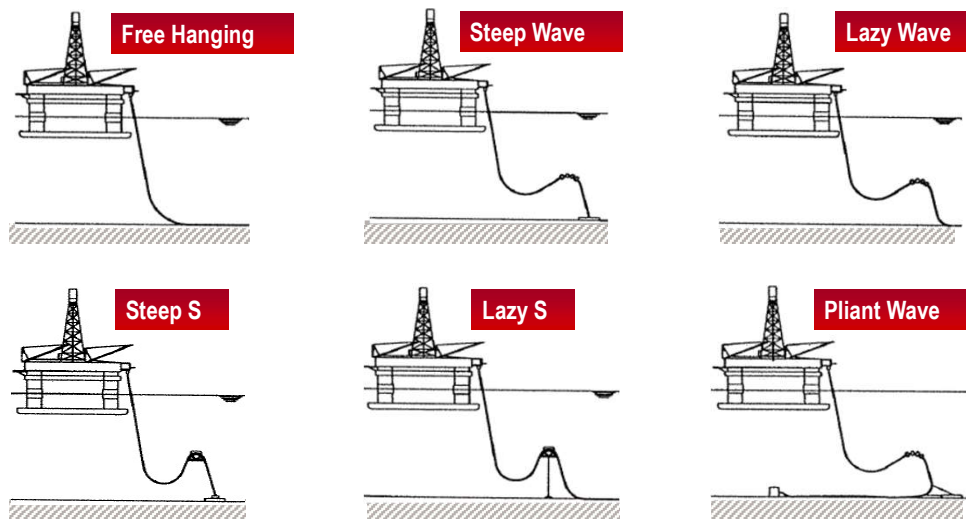
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Flexible Riser Configuration



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Flexible Risers – Additional Equipment



End Fitting



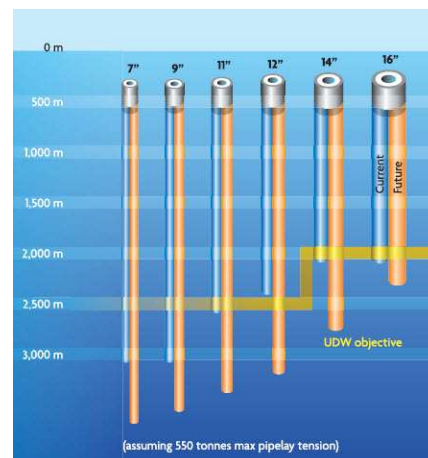
Buoyancy Module



Bend Stiffener

Flexible Riser – Limitations

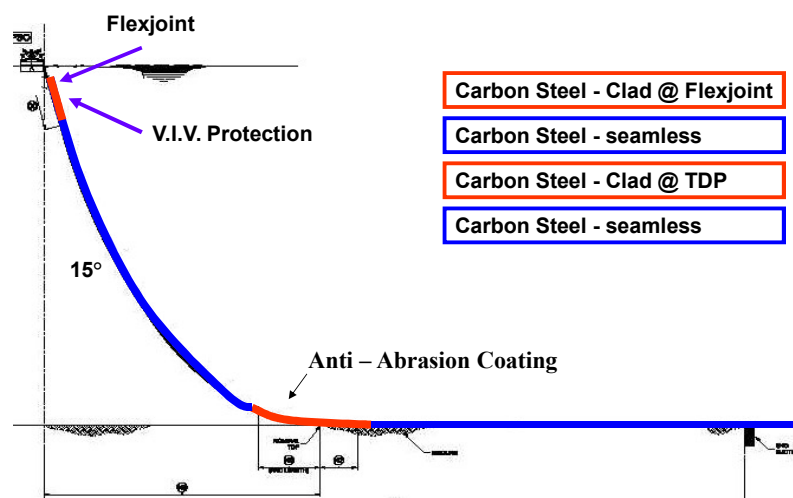
- ❑ Flexible Risers – suitable for most FPSOs
- ❑ Limitations :
 - Diameter (approx. 16 ins max)
 - Water depth
 - Temperature - polymer layers



Technip

Steel Catenary Risers (SCR)

SCR General Components



SCR Components



Flex Joint + VIV Strakes

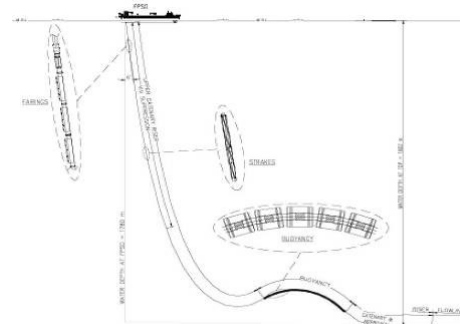
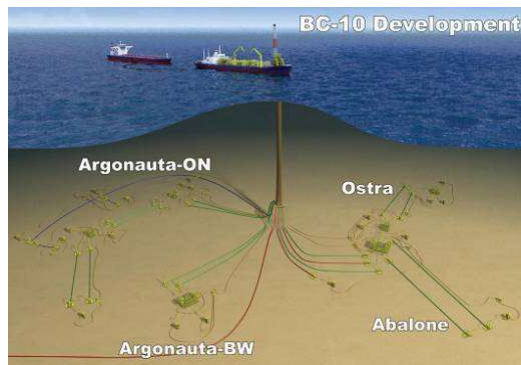


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Steel Lazy Wave Riser



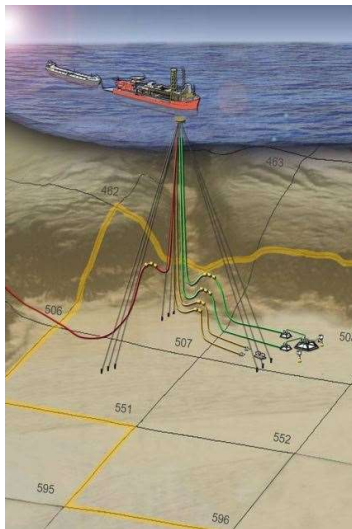
Ref OTC2010 - 20605

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Steel Lazy Wave Riser



Stones Field Development - Shell

- FPSO – owned and operated by SBM
- 2900m in Gulf of Mexico
- Using Steel Lazy Wave Risers (SLWR)
- Buoyant Turret Mooring System
- First oil September 2016
- First use of SLWR with disconnectable turret

(Shell + SBM)

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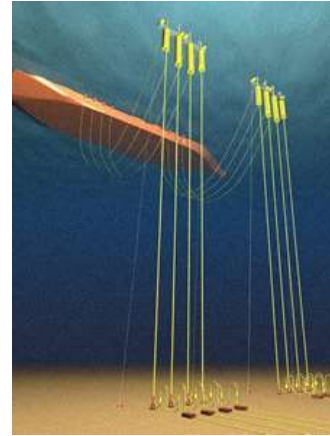
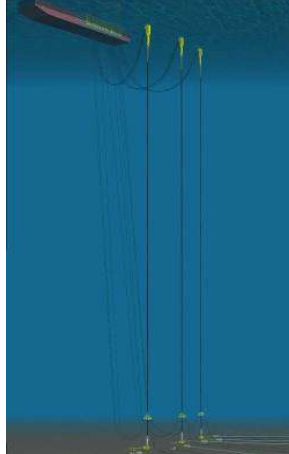
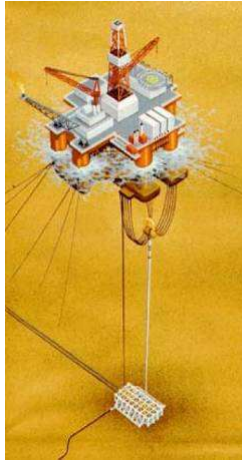
Hybrid Risers

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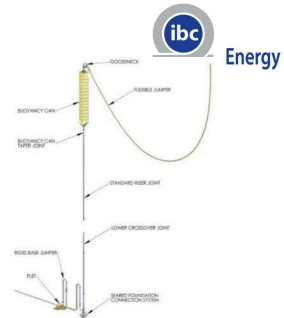


Hybrid Risers

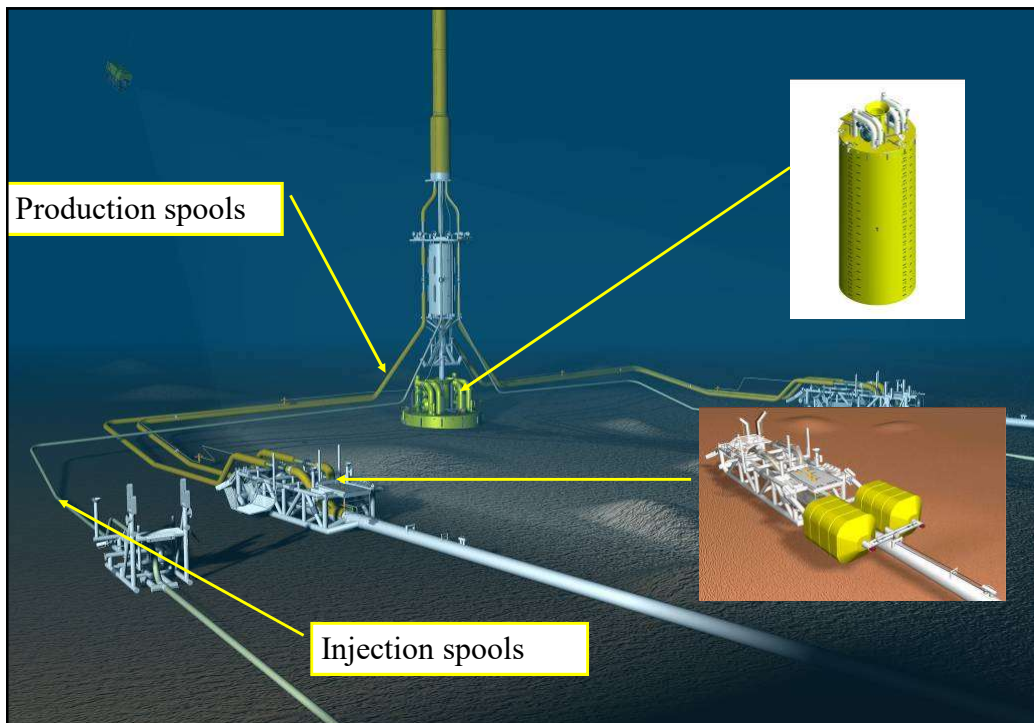
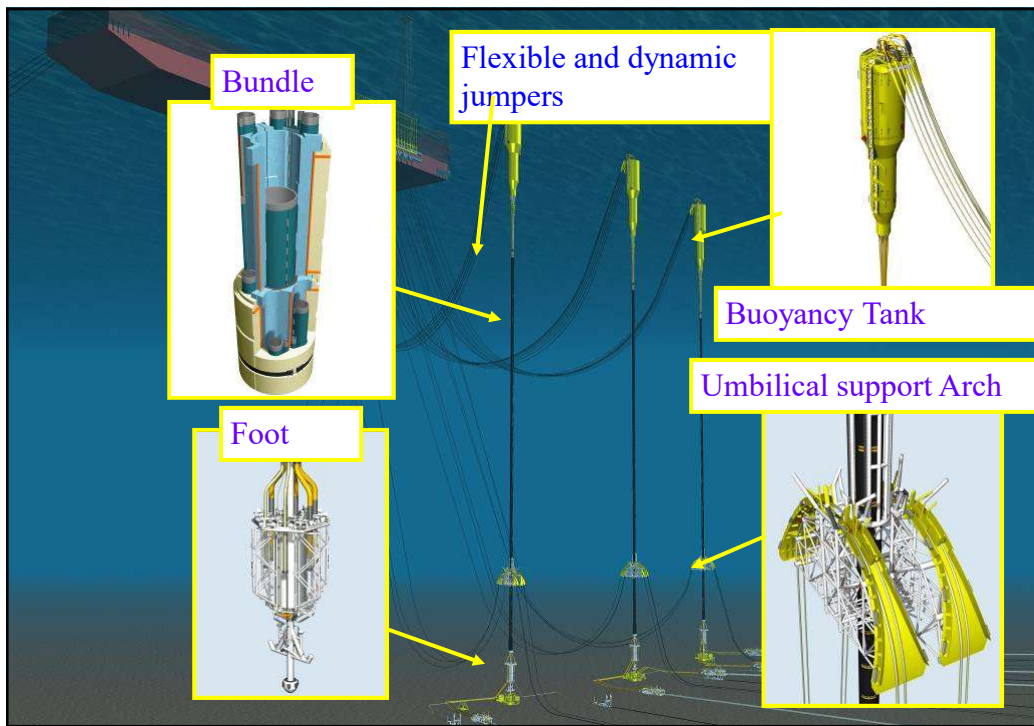


Hybrid Risers – general

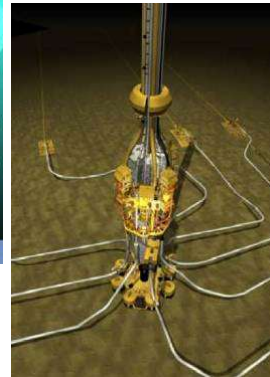
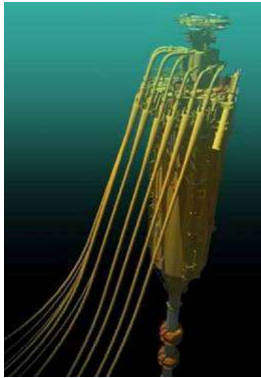
- Deep water riser solution
- Decoupled from FPS motions
- Minimal loads on FPS
- Provides flexibility for field expansion
- Insulation provided – coating/pipe-in-pipe
- Usually installed before FPS
- Single Leg Hybrid Riser :
 - Offshore fabrication using pipelay vessels
 - No fabrication site required
- Hybrid Riser Towers:
 - Built onshore - local content
 - Suitable fabrication site required
 - Large buoyancy tank required
 - Installed without need for pipelay vessel
 - Additional risers can be built into bundle



Grt Plutonia(Ref : OTC2008-19676)



Greater Plutonio Hybrid Riser Tower



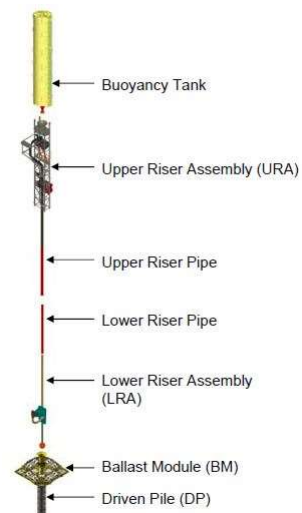
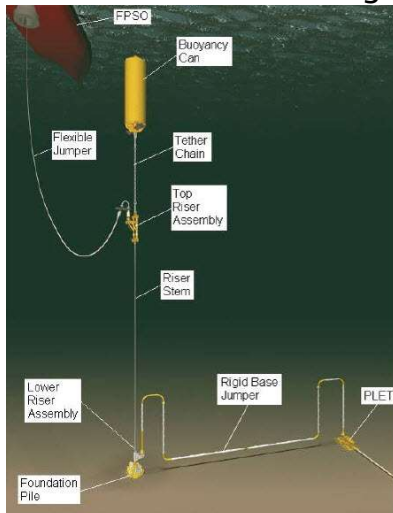
Ref : OMAE2009-79015

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Single Leg Hybrid Risers



iscade - Chinook (Ref : OTC2011- 21395)

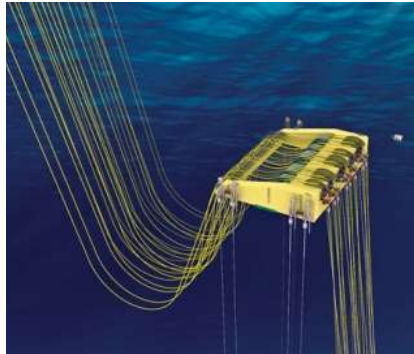
PSVM (Ref : DOT 2013)

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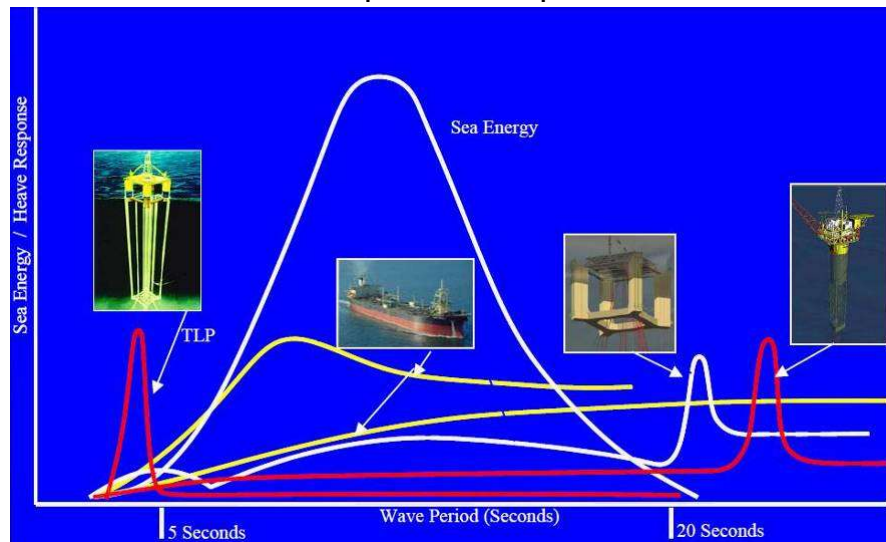
Alternative Hybrid Risers



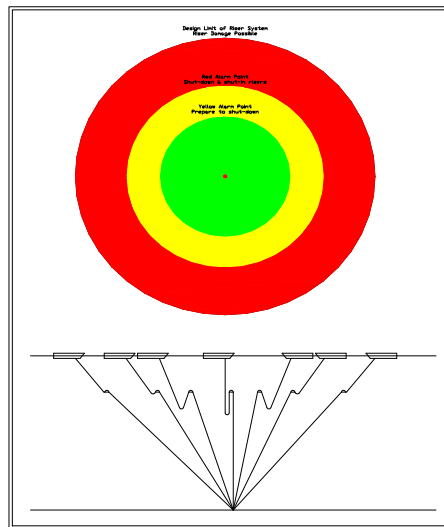
Buoyancy Supported Riser (BSR)
Subsea 7 - Guara-Lula NE field,
Brazil
(Ref: OTC2014 - 25165)

- Combination of SCR and Flexible risers
- Supported by submerged buoy
- SCR from seabed to buoy
- Flexible for buoy to FPSO

FPS Response Comparison



Riser Design Envelope



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Riser Design/Analysis



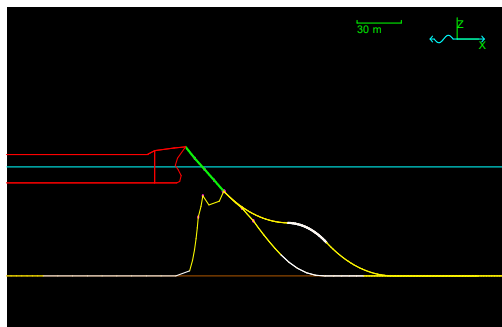
- Determine functional requirements
- Internal structure design
- Identify suitable riser configuration (shape)
- Evaluate riser buoyancy requirements
- Riser Minimum Bend Radius (MBR)
- Riser/riser clearance
- Riser/mooring clearance
- ALSO Umbilical behaviour (MBR etc)
- Riser maximum tension
- Riser fatigue

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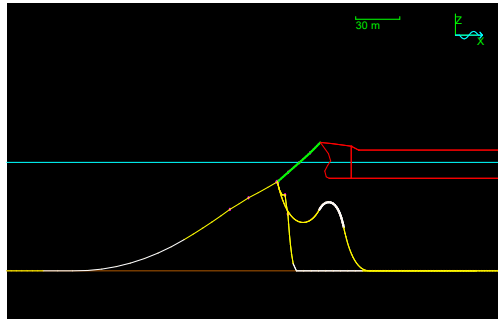


Riser Analysis

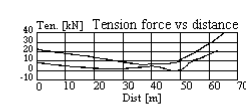
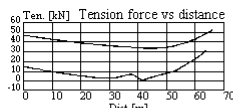
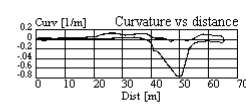
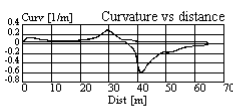
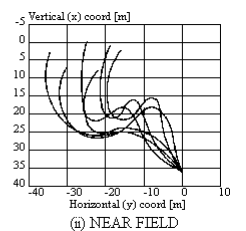
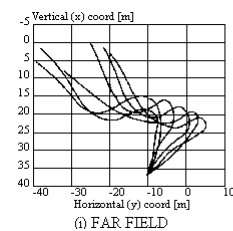
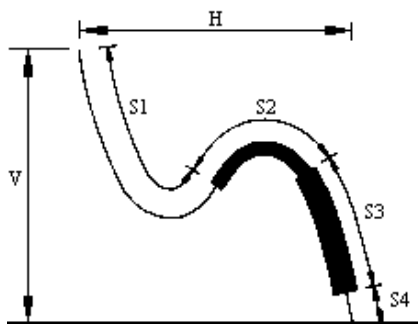


Far condition

Near condition



Flexible Riser Analysis



From node 1 to node 66
(i) FAR FIELD

From node 1 to node 66
(ii) NEAR FIELD

Riser Analysis – extreme load case matrix



Extreme Load Case Matrix									
System State	Contents Density	Environment (Waves-Current)	Temp./Pressure. (Air/Riser)	Vessel Draft, Water Level	Vessel Offset Direction	Inst. Tolerances Neighbours	Environmental Vessel Loading	Wave Period	System Operation
SOL, No MG	Min	100YW-10YC	Hot/Min.	Fully Loaded, LAT	N	Opposite Dir. Same Dir.	Transverse +	Upper	Intact System
	Max	10YW-100YC	Cold/Max.	Intermediate, MSL	NNE		Parallel	Critical	Damaged MWA
EOL, MG	Min	100YW-10YC			NE (Cross -)		Transverse -	Lower	Broken Mooring
	Max	10YW-100YC			ENE				
PRE-INSTALL	Min	10YW-1YC			E				
	Max	1YW-10YC			ESE				
INITIAL/TEST/ MAINTENANCE	Min	10YW-1YC			SE (Far)				
	Max	1YW-10YC			SSE				
	Min	10YW-1YC			S				
	Max	1YW-10YC			SSW				
	Min	10YW-1YC			SW (Cross +)				
	Max	1YW-10YC			WSW				
	Min	10YW-1YC			W				
	Max	1YW-10YC			VNW				
	Min	10YW-1YC			NW (Near)				
	Max	1YW-10YC			NNW				
13x			2x	3x	16x	2x	3x	3x	3x
No. Load Cases:		62208							

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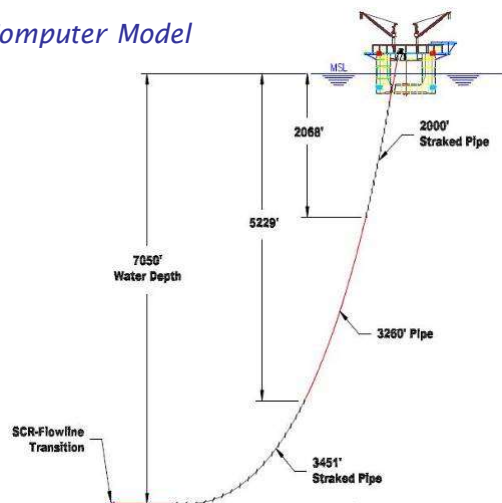
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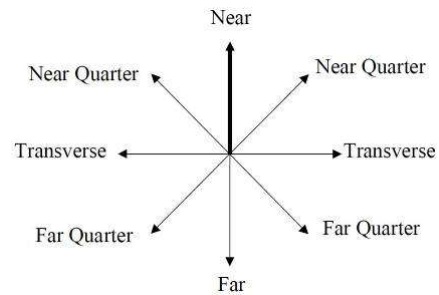
SCR Analysis



Computer Model



Load Cases



Ref : OMAE2009-79405

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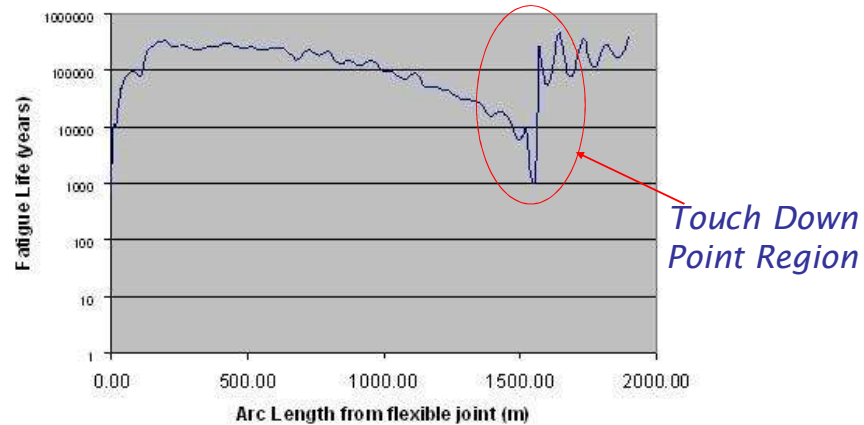
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SCR Fatigue Life Distribution



SCR typical fatigue Life



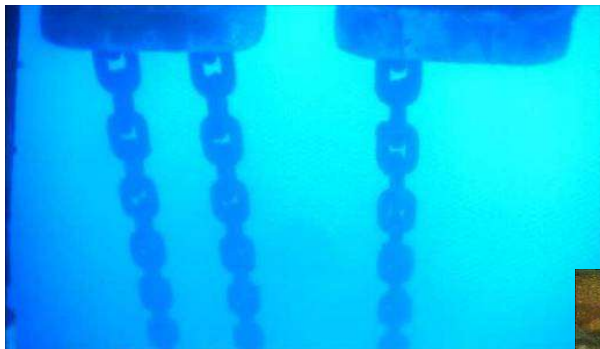
Integrated Mooring/Riser Analysis



- Historically treated as two different systems
- Technical issues include:
 - Damping from risers
 - Mooring-riser interference
 - Riser torsion
 - Vessel offset optimization
- Software available for integrated analysis
- Minimizes the danger of errors transferring between different analysis software
- Contractual issues to be overcome

Mooring System Integrity

Anything wrong ?



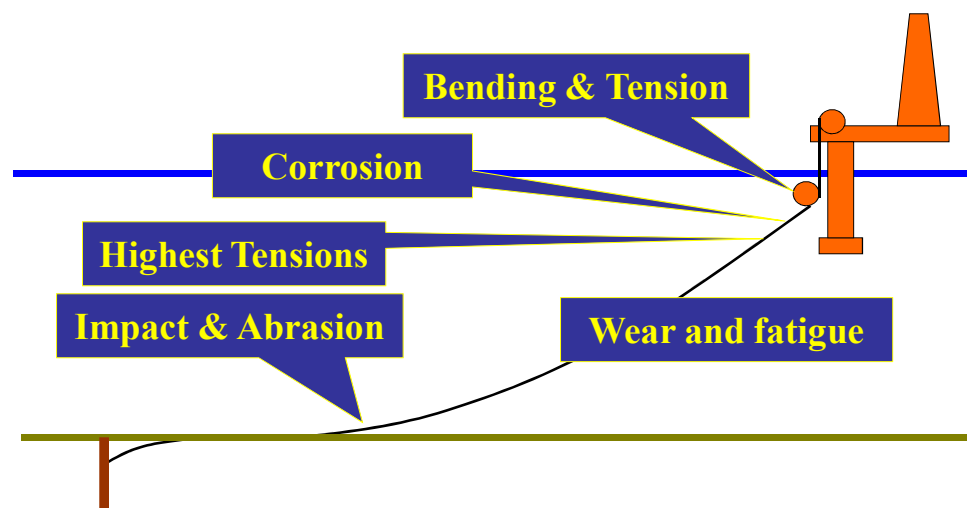
Commercial Consequences of Line Failure but no Stationkeeping Loss

- ❑ Cost of downtime/deferred production
- ❑ Cost and duration of repair operation, long lead time for replacement components



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Loading Mechanisms



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Chain Issues – corrosion + wear



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Mooring System Inspection – Sockets



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Mooring System Inspection – Wire Twisting



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OTC and JIP



OTC 17499



Floating Production Mooring Integrity JIP – Key Findings

Martin G. Brown, Noble Denton Europe Limited
Tony D. Hall, Welaptega Marine Limited
Douglas G. Marr, Balmoral Marine Limited
Max English, U.K. Health and Safety Executive
Richard O. Snell, B.P. Exploration

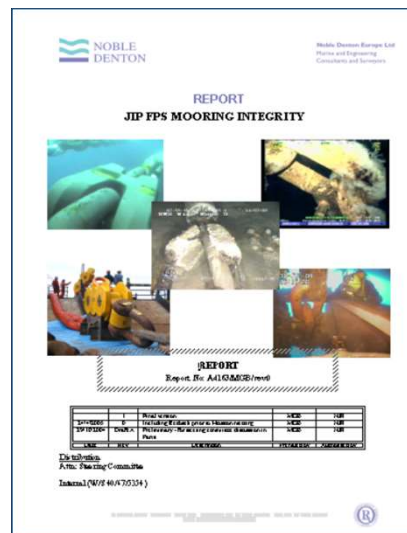


OTC 20613

Phase 2 Mooring Integrity JIP – Summary of Findings

Martin G. Brown, Andrew P. Comley, Morten Eriksen, GL Noble Denton
Ian Williams, Wood Group Engineering (North Sea) Ltd
Philip Smedley, BP Exploration Operating Company Limited
Subir Bhattacharjee, ExxonMobil Production Engineering

Copyright 2010, Offshore Technology Conference



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Summary and Conclusions

Summary

☐ Overview of FPSO Moorings & Risers Presented

☐ Key Issues Include

- **Moorings selected for FPSO**
- **Moorings there to keep within offset limits of riser**
- **Risers : flexible / SCR / hybrid**
- **Mooring – Riser interaction**
- **Consideration of integrity issues**

Thank You

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