2013-2014 Master in Petroleum Engineering and Operations

Asset Integrity For Floaters

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Stage Subject
Asset Integrity For Floating Production Units

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Stage Subject

Asset Integrity For Floating Production Units

Project Scope

- Introduction to FPSO
- The Floating fleet under direct operatorship
- Applicable rules and standards for FPSO management
- Asset Integrity Introduction
- Asset Integrity management for FPSO
- Conclusions
Project Scope

- **Introduction** to the floating production units with a special focus on floating production storage offloading (FPSO).
- **Preliminary Study** of applicable rules and standards to manage the integrity of an FPSO.
- **Synthetic research** to develop an asset integrity system for FPSO.
List of Content

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Introduction To FPSO

A floating production, storage and offloading (FPSO) unit is a floating vessel used by the offshore oil and gas industry for the production, processing of hydrocarbons and for storage of oil. An FPSO vessel is designed to receive hydrocarbons produced by itself or from nearby platforms or subsea template, process them, and store oil until it can be offloaded onto a tanker or, less frequently, transported through a pipeline.
The FPSO concept allows oil companies to produce oil in more remote areas and in deeper water than would have been economically possible with other technology, like fixed piled structures.

The ability to refurbish or upgrade the FPSO to tie-in additional fields or use in other projects; and

The mobility of the FPSO and relative ease of decommissioning.

The FPSO is used to recover petroleum discovered and developed by a company (or more commonly a joint venture) under an exploration permit and production license.
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  - Asset integrity Introduction
  - Asset Integrity Management for FPSO
  - Conclusions
## Floating units in Eni Business

<table>
<thead>
<tr>
<th>TYPE</th>
<th>COUNTRY</th>
<th>FPSO OWNER</th>
<th>FPSO OPERATOR</th>
<th>FIELD OPERATOR</th>
<th>OPERATED BY ENI</th>
<th>NOME FPSO</th>
<th>FIELD</th>
<th>STORAGE CAPACITY BRLS x 1,000</th>
<th>NEWBUILT OR CONVERSION</th>
<th>YEAR</th>
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<td>SAKI-BATUCUE (KIZOMBA C)</td>
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</table>
Firenze FPSO was built by saipem in the year 1989 in jugoslavia, it was converted from a trading Tanker vessel to FPSO in 2011 in Dubai. The FPSO was bought from saipem in 2013. she is presently in operation in the Aquila field in offshore Brindisi, Southern Adriatic Sea. Italy. It has a production capacity of 12,000 barrels per day.

**Vessel:**
- Aframax type
- Double Hull
- 93500 DWT
- 238 m Length
- 42,48 m Breadth
- 20,70 m Depth
- Accommodation for 56 people

- Liquids (Oil + water) 18,000 BPD
- Gas production 205,000 Sm3/d
- Gas lift 300,000 Sm3/d
- Water production 1,500 Sm3/d
- Storage capacity: 700,000 bbl
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Asset Integrity For Floating Production Units

- Project Scope
- Introduction to FPSO
- The Floating fleet under direct operatorship
- **Applicable rules and standards for FPSO management**
- Asset integrity Introduction
- Asset Integrity Management for FPSO
- Conclusions
Applicable rules and Standards for FPSO Management

- International rules and regulations (IMO convention, ISM/ISPS, MARPOL, SOLAS)
- Coastal State Regulations
- Flagging
- Classification of Society
Asset Integrity Introduction

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- Conclusions
“An asset has integrity when it is operated and maintained so that the combination of the likelihood of failure and the consequence of failure makes the risk to people, to the environment, and to the company as low as reasonable practical”. 
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- **Asset Integrity Management for FPSO**
- Conclusions
“The Primary concern of the FPSO asset integrity management is to maintain the asset in a fit-for-service condition while extending its remaining life in the most reliable, safe, and cost-effective manner. In addition to regulatory and company requirements”
Out of the typical asset integrity issues for conventional production plant (topside), the distinctive features of floating production unit can be grouped under the headings:

- Hull structural integrity
- Hull watertight integrity
- Station keeping
- Turret/swivel
- Marine systems
AIM for FPSO-Hull Structural Integrity

Hull Structural Integrity

Strength, Fatigue & Damage
- Fatigue Analysis
- Strength Analysis
- LOF Structural Capability
  - Structural Inspections
  - Pontoons
  - Slatting members
  - Bracing Joints
  - Well Tanks
  - Storage Tanks
  - Column
  - Void spaces
  - Upper Deck
  - Cargo Tanks
  - Slosh Tanks
  - Bilge Tanks
  - Other Tanks (AR)
  - Ship Type Hull Structure
  - Pump Room
  - Void Spaces
  - Bilge Keels
  - Caissons

Corrosion Protection (Coating + Anodes)
- Upper Dock
  - Bottom to Waterline
  - Waterline to Upper Deck
  - Turret
  - Mooring
  - Roustabout
  - ICCP System
  - Sea Chests
- External Hull
  - Helideck
  - Floe Tower
  - Crane Foundations
  - Process Module Structure
  - Accommodation
- Other Structures
  - Cargo Tanks
  - Ballast Tanks
  - Void Spaces
  - Machinery Spaces

Primary Structures
- Equipment Foundations
- Module Support Stacks
- Primary Structures
- Process Module Structures
- Cargo Foundations & Integration with Hull Structure
- Helideck Structure
- Mooring Structure
- Turret Shield/Swivel Support Structure
- Ground Floor Floe Tower Structure
- Towing and Mooring Arrangements
- Hose Rool
- Winches
- Offloading System
AIM for FPSO-Hull Structural Integrity

The bow-tie diagram below outlines what is considered the typical/minimum prevention and mitigation barriers that are expected to be in place along with additional recommended barriers required to understand the integrity of the installation and to manage the ageing of the hull structure.
## AIM for FPSO-Hull Structural Integrity

### Strength Fatigue and Damage:

<table>
<thead>
<tr>
<th>Elements</th>
<th>Ageing Mechanism</th>
<th>Controls</th>
<th>Life Extension Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life of field Assessment:</td>
<td>I. Strength and stability Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>II. Fatigue Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ship type hull structure</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Increased Field Life</td>
<td>Structural Inspections to Verify</td>
<td>Structural re-evaluation using up to date methods.</td>
</tr>
<tr>
<td></td>
<td>Change in Loading/ Offloading pattern</td>
<td>performance against analysis results.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Corrosion</td>
<td></td>
<td>Fatigue analysis based on historical load, heading and</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>metocean data.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Verification of analysis against</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>inspection findings.</td>
</tr>
<tr>
<td></td>
<td>Cyclic loading</td>
<td>Structural inspections</td>
<td>Robust integrity management strategy.</td>
</tr>
<tr>
<td></td>
<td>Cumulative impact of Peak loads</td>
<td>Structural anomaly management.</td>
<td>Increased Inspection frequency and scope.</td>
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<tr>
<td></td>
<td>Modifications</td>
<td>Loading/ offloading procedure</td>
<td>Re-analysis to improve understanding of loads.</td>
</tr>
<tr>
<td></td>
<td>- Increased structural loads</td>
<td></td>
<td>Understand how to carry out repairs.</td>
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<tr>
<td></td>
<td>- Collision damage</td>
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<tr>
<td></td>
<td>- Corrosion</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Vibration</td>
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### Corrosion Protection:

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<th>Controls</th>
<th>Life Extension Actions</th>
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<tbody>
<tr>
<td><strong>External Hull</strong></td>
<td>Impact damage, Marine growth, Anode depletion, Structural behaviour, Coating disbondment</td>
<td>Anti fouling inspection assessment, ICCP testing, Anode Surveys</td>
<td>Corrosion threat assessment, Anode renewal, Evaluate ICCP system Performance using inspection findings and review operating procedures</td>
</tr>
<tr>
<td><strong>Internal Hull</strong></td>
<td>Traffic and impact damage, Erosion, Coating disbondment, Change of tank, Service/maximum water levels, Increased in service temperature, Scale/sludge build up</td>
<td>Coating Inspection, Anode surveys, Tank Washing, Demucking</td>
<td>Corrosion threat assessment, Anode renewal, Review Coating suitability for current service, Operating philosophy, Coating repair and renewal procedures</td>
</tr>
<tr>
<td><strong>Topsides structures including:</strong> Flare tower, cranes, process modules, turret, towing and mooring arrangements, offloading system, accommodation</td>
<td>Coating disbondment</td>
<td>Coating inspection</td>
<td>Corrosion threat assessment, Review existing coating specifications and performance to establish inspection/repair/replacement philosophy</td>
</tr>
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</table>
AIM for FPSO-Hull Watertight Integrity

Hull Watertight Integrity

Sea Chests
- Valves
- Hydraulics
- Control Systems
- Structure
- Stub Pieces
- Ship side Valves

Overboards
- Pipe Penetrations
- Connection Pipework
- Valves
- Hydraulics
- Control Systems
- Ship side Valves

Watertight Doors
- Structure
- Hydraulics
- Control Systems

Weathertight Doors, Hatches and Closing Appliances
- Structure
- Seals and Sealing Arrangements
- Securing Arrangements
<table>
<thead>
<tr>
<th>Elements</th>
<th>Ageing Mechanism</th>
<th>Controls</th>
<th>Life Extension Actions</th>
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</thead>
<tbody>
<tr>
<td>Sea chests and stub pieces</td>
<td>Corrosion</td>
<td>Coating, Inspection</td>
<td>Procedures to inspect and maintain (filling of blanks etc)</td>
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<td>Valves</td>
<td>Corrosion, Erosion..</td>
<td>Inspection, Testing</td>
<td>Obsolescence assessment, Modifications, Valve replacement</td>
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<td>Hydraulics and control systems</td>
<td>Corrosion, Physical damage</td>
<td>Testing, Inspection</td>
<td>Obsolescence assessment, Corrosion assessment, Spares.</td>
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AIM for FPSO-Station Keeping

Station Keeping

Spread Moored Systems
- Chain stopper
- Fairleads
- Chain tensioning system
- Mooring Winches

Heading Control + Mooring Assist
- Diesel Power Generation (Propulsion & Thrusters)
  - Seals
  - Bearings
  - Shafting
- Main Propulsion Train
  - Propellers
- Thrusters
  - Electric Motor
  - Propellers
  - Hydraulics
  - Control System
- Rudders
  - Rudder Structure
  - Steering Gear
  - Bearings
  - Shafts

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AIM for FPSO-Station Keeping

<table>
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<th>Cause</th>
<th>Prevention Barriers</th>
<th>Mitigation Barriers</th>
<th>Consequence</th>
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<td>PropShaft Bearing Failure</td>
<td>Original BOO, Operating to Design, Maintain Regime, Studies to Understand, Inspection</td>
<td>Emergency Response Procedures, Critical Span, Heading Control Tags</td>
<td>Mooring Failure</td>
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<td>PropShaft Seal Failure</td>
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<td>Emergency Response Procedures, Critical Span, Heading Control Tags</td>
<td>Riser Failure</td>
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<tr>
<td>Propeller Failure</td>
<td>Original BOO, Operating to Design, Studies to Understand, Inspection</td>
<td>Emergency Response Procedures, Critical Span, Heading Control Tags</td>
<td>Disconnect</td>
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<td>Thruster Failure</td>
<td>Original BOO, Operating to Design, Studies to Understand, Inspection</td>
<td>Emergency Response Procedures, Critical Span, Heading Control Tags</td>
<td>Dry-Dock</td>
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<tr>
<td>Rudder Failure</td>
<td>Original BOO, Studies to Understand, Inspection</td>
<td>Emergency Response Procedures, Critical Span, Heading Control Tags</td>
<td>Loss of Life</td>
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</table>

Additional remarks:
- Likely off-station event
- Minimum/typical barrier
- Additional barrier to manage ALE issues

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## AIM for FPSO-Station Keeping

<table>
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<th>Elements</th>
<th>Ageing Mechanism</th>
<th>Controls</th>
<th>Life Extension Actions</th>
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<tbody>
<tr>
<td>Spread moored systems including: mooring attachment points and riser connections</td>
<td>Increased mooring loads due to modifications, Changes in metocean data.</td>
<td>Inspection/NDT</td>
<td>Revise Mooring analysis</td>
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<tr>
<td>Heading control and mooring Assistance</td>
<td>Wear obsolescence</td>
<td>Inspection/NDT, Maintenance, Head monitoring</td>
<td>Revise operating methods and controls, Revise system Performance, Reliability and spare availability.</td>
</tr>
</tbody>
</table>
AIM for FPSO-Turrets And Swivels

Turrets and Swivels

Turret
- Drive Motor + Gear System
  - Bearings
    - Radial
    - Axial
  - Mooring Winches
  - Turret Structure
  - Fairleads
    - Chain Hawse Pipes
    - Chain Stopper

Swivel
- Seals
- Hoses
- Silt Barriers
- Main Bearing
  - Other Swivel Bearings

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AIM for FPSO-Turrets And Swivels

Loss of Functionality of the Turret Bearing or Swivel

Cause
- Turret Bearing Failure
- Swivel Seal Failure
- Swivel Bearing Failure
- Mooring/Winch
- Chain Hawsers Pipe Failure
- Fairlead Failure

Prevention Barriers
- Original B.O.D.
- Operating to Design
- Maintain Regime
- Studies to Understand
- Inspection

Mitigation Barriers
- Emergency Response Procedures
- Critical Spares
- Heating Control Tags

Consequence
- Mooring Failure
- Riser Failure
- Disconnect
- Dry-Dock
- Loss of Life
- Loss of Production
- Reputation Damage

Potential off-station event
- Minimum/typical barrier - Steady

Additional barrier to manage ALE issues
## Turret:

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<th>Elements</th>
<th>Ageing Mechanism</th>
<th>Controls</th>
<th>Life Extension Actions</th>
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<tbody>
<tr>
<td>Systems including:-</td>
<td>Increased bearing loads due to wear, Increased friction, Increased loads to</td>
<td>Inspection/NDT, Lubrication, Swivel torque</td>
<td>Verify heading analysis assumptions with historic records(weather vanning units only),</td>
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<tr>
<td>Mooring attachment arrangements, bearings,</td>
<td>additional windage arising from modifications.</td>
<td>monitoring, Grease analysis, Bolt torque</td>
<td>Review bearing/elastomer suitability for anticipated service life loads.</td>
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<tr>
<td>drive</td>
<td></td>
<td>checks, Elastomer inspections, Bearing</td>
<td>Develop &quot;off the shelf&quot; work packages for repair.</td>
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<tr>
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<td>inspections-wear down, Head monitoring.</td>
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### AIM for FPSO-Turrets And Swivels

**Swivel:**

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<th>Life Extension Actions</th>
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<tr>
<td>Systems including:</td>
<td>Increased bearing loads due to wear,</td>
<td>Inspection/NDT, Lubrication, Swivel torque monitoring,</td>
<td>Verify heading analysis assumptions with historic records (weather vanning units only),</td>
</tr>
<tr>
<td>- Mooring attachment arrangements, bearings,</td>
<td>Increased friction, Increased loads to additional windage arising from modifications.</td>
<td>Grease analysis, Bolt torque checks, Elastomer inspections,</td>
<td>Review bearing/elastomer suitability for anticipated service life loads.</td>
</tr>
<tr>
<td>drive</td>
<td></td>
<td>Bearing inspections-wear down, Head monitoring.</td>
<td>Develop “off the shelf” work packages for repair.</td>
</tr>
</tbody>
</table>
## Cargo Systems:

<table>
<thead>
<tr>
<th>Elements</th>
<th>Ageing Mechanism</th>
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<th>Life Extension Actions</th>
</tr>
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<tbody>
<tr>
<td><strong>Cargo pumps</strong></td>
<td>Wear, Erosion, Obsolescence.</td>
<td>Condition Monitoring, Regular maintenance.</td>
<td>Obsolescence assessment.</td>
</tr>
<tr>
<td><strong>Cargo pipework, couplings and valve</strong></td>
<td>Obsolescence, Corrosion/Erosion, Seal/Seat failure, Cyclic stresses, Pipe support failure</td>
<td>Inspection.</td>
<td>Fatigue assessment, Corrosion assessment.</td>
</tr>
<tr>
<td><strong>Control systems (hydraulics, actuators, instruments)</strong></td>
<td>Obsolescence, Corrosion, Mechanical damage, Hydraulic contamination.</td>
<td>Function testing, Visual inspection, Hydraulic oil sampling/testing.</td>
<td>Review of performance, and reliability and redundancy of system. Review spare availability</td>
</tr>
<tr>
<td><strong>Slop tank pipework and valves</strong></td>
<td>Obsolescence, Corrosion/Erosion, Seal/Seat failure, Cyclic stresses, Pipe support failure</td>
<td>Inspection.</td>
<td>Corrosion assessment</td>
</tr>
<tr>
<td><strong>Cargo washing systems and guns</strong></td>
<td>Vibration, Leakage, corrosion</td>
<td>inspection</td>
<td>Review spares availability</td>
</tr>
<tr>
<td><strong>Offloading systems including hose reel</strong></td>
<td>Wear, Corrosion, Mechanical damage, Elastomer degradation</td>
<td>inspection, hawser load history and sensor calibration, corrosion protection.</td>
<td>Obsolescence assessment, Fatigue assessment.</td>
</tr>
</tbody>
</table>
Inert Gas:

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<td><strong>Cargo washing systems and guns</strong></td>
<td>Vibration, Leakage, corrosion.</td>
<td>inspection</td>
<td>Review spares availability</td>
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<td><strong>Offloading systems including hose reel</strong></td>
<td>Wear, Corrosion, Mechanical damage, Elastomer degradation</td>
<td>inspection, hawser load history and sensor calibration, corrosion protection.</td>
<td>Obsolescence assessment, Fatigue assessment.</td>
</tr>
<tr>
<td><strong>Heating coil</strong></td>
<td>Vibration, Leakage, Mechanical damage, corrosion</td>
<td>Inspection, Leak testing, Heat testing, Contamination checks, Boiler water treatments.</td>
<td>Corrosion assessment, Spares.</td>
</tr>
<tr>
<td>Internal lining/coating damage.</td>
<td>Inspection and testing, Cleaning de-mister pads, Maintenance, Maintain coatings/linings, Check for water carry over, Dismantle level regulators/float valves</td>
<td>Corrosion assessment. Spares</td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
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</tr>
<tr>
<td>Corroded inlets/drains sticking valves/floats</td>
<td><strong>Corrosion</strong> (internal/External) Inspection/NDT Draining residual Water</td>
<td>Corrosion assessment</td>
<td></td>
</tr>
<tr>
<td>Loss of seal</td>
<td>Inspection, Maintenance</td>
<td>Obsolescence assessment, Corrosion assessment, Spares.</td>
<td></td>
</tr>
<tr>
<td>Obsolescence, Loss of accuracy</td>
<td>Regular maintenance and testing, Calibration of sensors</td>
<td>Obsolescence assessment, Corrosion assessment, Spares.</td>
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</tr>
</tbody>
</table>
### AIM for FPSO-Marine Systems

#### Ballast Systems:

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<td>Vibration testing,</td>
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<tr>
<td></td>
<td>Reduced efficiency,</td>
<td>Overhauling,</td>
<td>Corrosion assessment,</td>
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<td>Wear,</td>
<td>Inspection,</td>
<td>Spares.</td>
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<td></td>
<td>Corroded supports</td>
<td>Monitoring pressure.</td>
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<td></td>
<td>Cracking,</td>
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<td>Pipe Support failure.</td>
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<td>Loss of seal.</td>
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<td>Obsolescence assessment,</td>
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<td></td>
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<td>Maintenance.</td>
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<td></td>
<td>Spares.</td>
</tr>
<tr>
<td>Ballast system in machinery spaces</td>
<td>corrosion</td>
<td>Inspection.</td>
<td>Corrosion assessment.</td>
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<td>Reliability and redundancy of system,</td>
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<td>Hydraulic oil sampling/testing</td>
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### AIM for FPSO-Marine Systems

**Control Systems:**

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<td>Obsolescence modification</td>
<td>Inspection, Maintenance</td>
<td>System review, Obsolescence assessment</td>
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<td>Tank monitoring, flood detection and bilge system</td>
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Stage Subject

Asset Integrity for Floating Production Units

- Project Scope
- Introduction to FPSO
- The Floating fleet under direct operatorship
- Applicable rules and standards for FPSO management
- Asset integrity Introduction
- Asset Integrity Management for FPSO

- Conclusions
Conclusions

“The Effective Management of FPSO Asset Integrity Requires That Competent People With Sound Understanding of the Issues Take Effective Actions To Enable The Asset Continue to Function Safely For its Required Service Life. The Key is On the Build of Design, People, Understanding The Systems and Maintenance Strategy/Actions,” While Clearly Defining:

- Design for Asset Integrity
- Maintenance plan, inspection and Strategy/Approach Actions
- Corrosion inspection and maintenance plan
- Continuous Machinery Inspection/maintenance
- Development and Application of International Standards, Best Practices and Company Guidelines
I would thank Eni s.p.a. upstream and technical services Management for permission to present this work and related results and Management of Floaters/FIROP/LOGIS colleagues for the technical support and needed assistance.