New Generation Deepwater Drilling Risers
A Design Methodology
Introduction

- Ultra-deepwater, 10,000 feet
- 1996 turning point
- Doubling water depth = High Risk!!
- Existing Riser Designs Inadequate
- What would the rigs look like?
Previous Alternatives for Deepwater?

- Limiting the mud weight requirement;
- Running thicker-walled, higher strength (main tube) risers in the high stress regions;
- Investigations into lighter weight aluminum riser designs;
- Investigations into composite risers;
- Upgrading shallow water coupling designs with deeper couplings-limited to about 5,000 ft w.d.
- Design and Construct a New Generation Deepwater Riser
Design Challenges

- Manufacturing high strength connector bolts; Bolt and thread capacity design limits;
- Strength limitations of shallow water connector designs;
- Careful consideration of riser pressure end load effects, PEL, on both auxiliary lines and main tube seals;
- Loop current and VIV effects on the riser;
- Hurricane abandonment strategies require emergency disconnect systems, riser hang-off and centralizing;
- Gas migration into the riser and deepwater well control issues require gas handling equipment;
- Riser mass limitations during running and out-of-phase heave acceleration of vessel causing riser buckling after disconnect;
- Lack of adequate riser buoyancy industry design standards;
- Larger mud flow rate requirements because of higher pressure drops across choke/kill auxiliary lines.
Enabling Technologies

- Improvements in dynamic positioning of ultra deepwater drilling vessels;
- Improvements in thruster electro-mechanical drives;
- Availability of shipyards to design and build tanker hulls as drillships.
- Improvements in mooring winch systems for ultra-deepwater;
- Availability of high tolerance wall seamed pipe;
- More efficient riser design analysis programs and FEA tools;

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Enabling Technologies

- The construction of a new riser buoyancy plant in Houston;
- Improvements in buoyancy manufacturing quality control;
- Improvements in fabrication of high strength bolts for riser connectors;
- Direct acting riser tensioner technology;
- 60-inch rotary table development;
- Riser gas handling technology;
- Improvements in subsea control system designs.
## Water Depth/Tension Challenge

### WD = 5,000 ft

<table>
<thead>
<tr>
<th>Mud Weight (ppg)</th>
<th>TSR (kips)</th>
<th>Indicated Tension (kips)/API Rating</th>
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<tbody>
<tr>
<td>12</td>
<td>800</td>
<td>1,450/Type D</td>
</tr>
<tr>
<td>16</td>
<td>1,200</td>
<td>1,650/Type E</td>
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<tr>
<td>12</td>
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<td>1,900/Type E</td>
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<td>1,800</td>
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<td>14</td>
<td>2,000</td>
<td>2,400/Type F</td>
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<tr>
<td>16</td>
<td>2,700</td>
<td>3,500/Type H</td>
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</table>
Riser Components

Riser Spider
Rotary Table
Diverters
Upper Flexjoint
Tensioner
Tensioner Support Ring
Intermediate Flexjoint
Riser Joints
Riser Booster Line Joint
Lower Flexjoint
Mud Weight vs. Water Depth

Estimated Maximum Riser Operating Limits

MUD WEIGHT vs WATER DEPTH

MUD DENSITY, PPG

WATER DEPTH, FT

PPG/10,000 FT 14
ANALYSIS POINT

PPG/7,500 FT 16
ANALYSIS POINT

10,000 FT BASE CASE → 7500 FT 16 PPG REF CASE
Riser System

- Telescopic joint
- Tension support ring
- Hi-Press, Lg. Dia. C/K
- Riser Centralizer
- Riser Specialty Joints
- Gas Handling Joint
- Buoyancy Required?
- **Riser Disconnect!!!**
Telescopic Joint

- Highly loaded joint
- 4 knot design current
- 100 kip shear at joint
- 4,000,000 ft-lb bend.
- Limiting angle of 8.5deg
- Centralizing required
- Protection for Aux. Lines
Riser Centralizer

- Emergency Disconnect
- Drift-off or Drive-off
- Riser Slipjoint Captured
- Design for 100 kip lateral riser loading
Gas Handler

- Two Annulars
- Choke/Kill Hoses
- Control Umbilical
Buoyancy Design

- Module Strength
- Module Depth Rating
- Module Length
Specialty Joints

- Intermediate flexjoint
- Termination joint
Gas In Riser

- Gas Handler at top
- Safety issues
- Design impact
- Weight impact
- Cost impact
- Reduced riser collapse risk
# Drift-off Study Environments

<table>
<thead>
<tr>
<th>Environment Direction(s)</th>
<th>DPSIM CASE SERIES</th>
<th>Wave</th>
<th>Wind</th>
<th>Wind</th>
<th>Current</th>
<th>Current</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Hs</td>
<td>T mean</td>
<td>1 hour</td>
<td>1 hour</td>
<td>Velocity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>m</td>
<td>sec</td>
<td>m/sec</td>
<td>kts</td>
<td>m/sec</td>
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<tr>
<td>10 year Winter Storm</td>
<td>28000</td>
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<td>8.2</td>
<td>22.0</td>
<td>42.7</td>
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<tr>
<td>1-year Storm</td>
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<td>4.6</td>
<td>7.1</td>
<td>18.3</td>
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<tr>
<td>1-year Winter Storm + 10 Yr Loop Current</td>
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<td>5.0</td>
<td>7.2</td>
<td>15.0</td>
<td>29.0</td>
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</table>
Riser Disconnect Time Limits

1500’ Water Depth - DRIFT OFF

1500 ft Water Depth, Riser Angles vs. Vessel Offset and Time
1YR STORM + 10YR LOOP CURRENT, DRIFT OFF

- Vessel Offset (ft)
- Riser Angles (deg)
- Time (sec)

Graph showing the relationship between vessel offset and riser angles at various time intervals, indicating the impact of vessel offset on riser angles under specific environmental conditions.
Riser Disconnect Time Limits
1500’ Water Depth- DRIVE OFF

1500 ft Water Depth, Riser Angles vs. Vessel Offset and Time
1YR STORM + 10YR LOOP CURRENT

Vessel Offset (ft) vs. Time (sec)

- Time
- Flexjoint Angle
- Slip Angle
- Linear (Time)
- Slipjoint Angle Trend
- Lower Flexjoint Angle Trend
Riser Disconnect Time Limits

7500’ Water Depth DRIFT OFF

7500 ft Water Depth, Riser Angles vs. Vessel Offset and Time
1YR STORM + 10 YR LOOP CURRENT, DRIFT OFF

% Vessel Offset

Vessel Offset (ft) vs. Riser Angles (deg)

Time (sec)

Linear (Time) - Flexjoint Angle - Slipjoint Angle Trend - Lower Flexjoint Angle Trend
## ESD and DP Time Limits

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The Future Beyond 10,000 ft?

• Composite Riser Technology?
• Dual Gradient Drilling Technology?
• Slim Bore Riser Drilling?
It Does Happen!
Hurricane Ivan-DP with Riser