RTI ENERGY SYSTEMS PRESENTATION

“Deepwater Engineering Solutions Using Titanium”
The Devil is in the Detail

- TITANIUM PRODUCT APPLICATIONS
- DEEPWATER OFFSHORE PRODUCTION FACILITIES
- ENGINEERING, CONSTRUCTION & INSTALLATION
- HURRICANES
TITANIUM PRODUCT APPLICATIONS

EXPLORATION
– DRILLING RISER
– DRILL PIPE

PRODUCTION
– DOWN HOLE TUBING
– STRESS JOINTS
– PRODUCTION RISER
TITANIUM PRODUCT APPLICATIONS

• GEOTHERMAL MARKET
  – US SALTON SEA CALIFORNIA 1987

• DRILLING RISER
  – EUROPE NORTH SEA 1995

• DRILL PIPE
  – US LAND BASE 1999

• TAPERED STRESS JOINTS
  – EUROPE NORTH SEA 1996
  – US GULF OF MEXICO 1998
  – SOUTH EAST ASIA INDONESIA 2003
  – EUROPE CASPIAN SEA 2006
TITANIUM ATTRACTION

- High strength material
- Light weight material
- Metallic solution
- Corrosion resistant
- Temperature resistant
- Pressure resistant
- Reliable material that can be handled & inspected
TITANIUM DRILL PIPE

RAW PIPE ACCEPTS INDUSTRY ACCEPTED TOOL JOINTS

SHORT-RADIUS DRILLING:
- Dramatic extension of drill string life (fatigue life enhancement)
- More robust, damage-tolerant string

EXTENDED-REACH DRILLING:
- Torque and drag reduced
- Pull out loads reduced
- Topside equipment and power requirements reduced
- Radical extensions in reach (possibly double or more)
- Reduce the number of platforms or subsea completions for field development
- Robust, damage-tolerant, longer-life string

Ti-6Al-4V versus steel drill pipe in a 5.5” OD X 0.361” wall size

<table>
<thead>
<tr>
<th>Drill Pipe Alloy</th>
<th>Min. Yield Strength (ksi)</th>
<th>Tensile Yield Strength (lbs)</th>
<th>Torsional Yield Strength (ft-lbs)</th>
<th>Modulus of Elasticity ($10^6$ lb/in$^2$)</th>
<th>Adjusted String Weight* (lbs/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-135 Steel</td>
<td>135</td>
<td>786,810</td>
<td>91,300</td>
<td>30.0</td>
<td>26.35</td>
</tr>
<tr>
<td>G105 Steel</td>
<td>105</td>
<td>612,000</td>
<td>71,000</td>
<td>30.0</td>
<td>25.24</td>
</tr>
<tr>
<td>Ti-6Al-4V</td>
<td>120</td>
<td>699,430</td>
<td>81,100</td>
<td>16.5</td>
<td>15.97</td>
</tr>
</tbody>
</table>

* Adjusted for steel tool joints

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WEIGHT COMPARISON OF A CHOKE AND KILL LINE
TITANIUM VS STEEL

**MATERIAL PROPERTIES (TITANIUM)**
- Yield Strength: 110 KSI
- Ultimate Strength: 120 KSI
- Hardness: Rc 32 Max
- Density: 0.16 lbs/in³
- Modulus: 16 x 10⁶ PSI
- Coatings: Not Required
- NACE Approved: YES

**MATERIAL PROPERTIES (STEEL)**
- Yield Strength: 80 KSI
- Ultimate Strength: 93 KSI
- Hardness: Rc 22 Max
- Density: 0.283 lbs/in³
- Modulus: 30 x 10⁶ PSI
- Coatings: Required
- NACE Approved: YES

**TITANIUM LINE**
- Box Weight: 38 pounds
- Pipe Weight: 1,737 pounds
- Pin Weight: 38 pounds
- Total: 1,811 pounds

**STEEL LINE**
- Box Weight: 101 pounds
- Pipe Weight: 4,925 pounds
- Pin Weight: 112 pounds
- Total: 5,738 pounds

**Weight Savings Per 10,000 Feet of Drilling Riser:**
- Choke and Kill Line (2 per joint)-------- 7,854 pounds
- 133 - 75 foot joints------------------------1,044,582 pounds

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TENSION LEG PLATFORM

Products suitable for Titanium

- Tapered Stress Joints
- Production Riser
- Keel Joints
- Catenary Riser
- Tree Jumpers
- Coiled Tubing
DESIGN • ENGINEERING • MACHINING • FABRICATION • FIELD SERVICES
TENSION LEG PLATFORMS

Ursa

RamPowell

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WORLDWIDE SURVEY OF INSTALLED & SANCTIONED TLPS, TLWPS AND MINI TLPS

HUTTON 1984
SNORRE B 1992
HEIDRUN 1995
PRINCE 2001
MORPETH 1998
JOLLIE 1989
TYPHOON 2001
AUGER 1994
MARS 1996
BRUTUS 2001
MATTERHORN 2003
RAMP 1997
POWEL 1999
MARL 1999
ALLEHEN 1999
WEST SENO 1 2003
KIZOMBA 2003
URSA 1999
MAGNO 2004

148 m 486'
UK North Sea
335 m 1,100'
Norway
351 m 1,150'
Norway
457 m 1,500'
GOM
518 m 1,700'
GOM
536 m 1,760'
GOM
671 m 2,200'
GOM
872 m 2,860'
GOM
896 m 2,940'
GOM
910 m 2,985'
GOM
945 m 3,100'
GOM
980 m 3,214'
GOM
988 m 3,240'
GOM
910 m 3,280'
GOM
1,000 m 3,280'
GOM
1,021 m 3,349'
GOM
1,077 m 3,863'
GOM
1,225 m 4,018'
GOM
1,311 m 4,018'
GOM
1,432 m 4,700'
GOM

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TITANIUM DEEPWATER INSTALLATIONS

TEXAS

LOUISIANA

Gulf of Mexico Depths

3,280 ft.

4,920 ft.

6,560 ft.

9,840 ft.

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FACILITY WITH SUBSEA TIE BACK FIELDS
FACILITY versus FIELD
Angle of Declination & Azimuth
ENGINEERING DESIGN CODES

AMERICAN PETROLEUM INSTITUTE ~ API
API RP2D DESIGN STANDARD FOR
FLOATING PRODUCTIONS SYSTEMS (FPS) and TENSION LEG PLATFORMS (TLPs)
ENGINEERED PRODUCTS

ENGINEERING 3D MODELS

FACTORY SYSTEMS INTEGRATION

FIELD INSTALLATIONS
• Analysis of fixed structure and Flexible Jt
• Interface Strategies Titanium to Steel
• Isolation material
• Load Sharing Interface materials
TAPERED STRESS JOINTS

MAXIMUM BENDING MOMENT @ SUPPORT
STEEL: 1220 FT-KIPS
TITANIUM: 485 FT-KIPS

Steel TSJ
7520 lbs @ 65'

TITANIUM TSJ
1100 lbs @ 26'

MECHANICAL & PHYSICAL PROPERTIES

<table>
<thead>
<tr>
<th></th>
<th>STEEL</th>
<th>TITANIUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>YIELD STRENGTH</td>
<td>80 KSI</td>
<td>110 KSI</td>
</tr>
<tr>
<td>ULTIMATE STRENGTH:</td>
<td>93 KSI</td>
<td>120 KSI</td>
</tr>
<tr>
<td>MODULUS OF ELASTICITY:</td>
<td>30 x 10^6 PSI</td>
<td>16 x 10^6 PSI</td>
</tr>
<tr>
<td>DENSITY:</td>
<td>.283 lbs/in^3</td>
<td>.160 lbs/in^3</td>
</tr>
</tbody>
</table>
HIGHERLY ENGINEERED PRODUCT

FEA Model

3D MODEL
Basket & TSJ
STARTEGIC TECHNOLOGY
TITANIUM TO STEEL CONNECTION
CAPACITY ANALYSIS

Construct a Finite Element Model

- Use least material condition
- Employ stress strain curves for the Titanium
- Use equivalent tension to combine loads
PROTOTYP\EVENT\EXTING TO FIELD INSTALLATION

![Prototype testing in a workshop and in the field.](image)
J-LAY TSJ INSTALLATION
S-LAY TSJ INSTALLATION
INSTALLATION ANALYSIS

TSJ Loading

- Deployment over stinger
- Seabed recovery
- Final pull-in
- Hydrotest
TITANIUM STRESS JOINT INSTALLATION
TITANIUM

RTI Energy Systems Titanium Production Pipe

Outside Diameter, (inch)

Wall Thickness, (inch)
PIPE SUPPLY
## TITANIUM STRESS JOINTS

### TOP TERMINATION
- Macaroni (Shell)
  - Qty: 2
  - Yr: 1997
- Allegheny (British Borneo)
  - Qty: 7
  - Yr: 1999
- King Kong (Mariner Energy)
  - Qty: 1
  - Yr: 1999
- Yosemite (Mariner Energy)
  - Qty: 1
  - Yr: 1999
- King (BP)
  - Qty: 2
  - Yr: 2002
- K2 (ENI)
  - Qty: 2
  - Yr: 2004
- GC518 (Anadarko)
  - Qty: 2
  - Yr: 2004
- Horn Mountain (BP)
  - Qty: 1
  - Yr: 2004
- Genghis Khan (Anadarko)
  - Qty: 2
  - Yr: 2005

### SUBSEA TERMINATION
- Green Canyon 29 (Placid)
  - Qty: 1
  - Yr: 1987
  - Refurbished for Ensearch Garden Banks
  - Yr: 1995
- Heidrun (Statoil)
  - Qty: 2
  - Yr: 1995
- Neptune (Kerr McGee)
  - Qty: 16
  - Yr: 1996
- West Seno A (Unocal)
  - Qty: 28
  - Yr: 2003
- BP (Shah Deniz)
  - Qty: 9
  - Yr: 2005
MANUFACTURING PRODUCTION PERFORMANCE
VERTICAL INTEGRATION

ENGINEERED TI ALLOYS
EXTRUSION CAPABILITIES
UNIQUE MACHINE LATHES

PROCESS VERIFICATION
SYSTEMS CAPABILITIES
FIELD SERVICE INSTALLATIONS

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RTIES – TITANIUM
READILY MACHINABLE
DESIGN CRITERIA
ENVIRONMENTAL AFFECTS ~ HURRICANES
## Table 1 – Environmental Conditions a

<table>
<thead>
<tr>
<th>Environmental conditions</th>
<th>Description</th>
<th>Wave</th>
<th>Wind</th>
<th>Current profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme</td>
<td>Extreme wave</td>
<td>100 yr.(^b) Hs/Tp varied</td>
<td>Associated(^a)</td>
<td>Associated(^c)</td>
</tr>
<tr>
<td></td>
<td>Extreme wind</td>
<td>Associated(^c)</td>
<td>100 yr.(^b)</td>
<td>Associated(^c)</td>
</tr>
<tr>
<td></td>
<td>Extreme current</td>
<td>Associated(^c)</td>
<td>Associated(^c)</td>
<td>100 yr.(^b)</td>
</tr>
<tr>
<td>Maximum Operating</td>
<td>Restricted conditions</td>
<td>See 4.3.1</td>
<td>See 4.3.1</td>
<td>See 4.3.1</td>
</tr>
<tr>
<td>Temporary</td>
<td>Installation/Retrieval Transportation</td>
<td>Seasonal(^d)</td>
<td>Associated</td>
<td>Associated</td>
</tr>
<tr>
<td>Fatigue</td>
<td>Fatigue conditions</td>
<td>WSD(^c)</td>
<td>Associated</td>
<td>Associated Annual Distribution</td>
</tr>
<tr>
<td></td>
<td>Wave VIV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Survival</td>
<td>Survival condition</td>
<td>See 4.3.6</td>
<td>Associated(^c)</td>
<td>Associated(^c)</td>
</tr>
</tbody>
</table>

### Notes:

\(^a\)The static vessel offset plus or minus the low frequency offset caused by wind and wave-drift forces should be included in the riser analysis.

\(^b\)May use less than 100-year event if risk consistent criteria are maintained.

\(^c\)Associated wind, current profile or wave to be determined by considering joint wind, wave and current probabilities.

\(^d\)Wave and current conditions should be based on the season during which the operation will take place, the duration of the operation and weather forecasting accuracy.

\(^e\)WSD = wave scatter diagram.
### DESIGN OF RISERS FOR FLOATING PRODUCTION SYSTEMS (FPSs) AND TENSION-LEG PLATFORMS (TLPs)

#### Table 2 – Design Matrix for Rigid Risers

<table>
<thead>
<tr>
<th>Design Case</th>
<th>Load Category</th>
<th>Environmental Condition (from Table 1)</th>
<th>Pressure</th>
<th>Reduced Tensioner Capacity or One Mooring Line Broken</th>
<th>$C_r^{ab}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Operating</td>
<td>Maximum operating</td>
<td>Design</td>
<td>No</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>Extreme</td>
<td>Extreme</td>
<td>Design</td>
<td>No</td>
<td>1.2</td>
</tr>
<tr>
<td>3</td>
<td>Extreme</td>
<td>Maximum operating</td>
<td>Extreme</td>
<td>No</td>
<td>1.2</td>
</tr>
<tr>
<td>4</td>
<td>Extreme</td>
<td>Maximum operating</td>
<td>Design</td>
<td>Yes</td>
<td>1.2</td>
</tr>
<tr>
<td>5</td>
<td>Temporary</td>
<td>Temporary</td>
<td>Associated</td>
<td>No</td>
<td>1.2</td>
</tr>
<tr>
<td>6</td>
<td>Test$^d$</td>
<td>Maximum operating</td>
<td>Test$^d$</td>
<td>No</td>
<td>1.35</td>
</tr>
<tr>
<td>7</td>
<td>Survival</td>
<td>Survival</td>
<td>Associated</td>
<td>No</td>
<td>1.5</td>
</tr>
<tr>
<td>8</td>
<td>Survival</td>
<td>Extreme</td>
<td>Associated</td>
<td>Yes</td>
<td>1.5</td>
</tr>
<tr>
<td>9</td>
<td>Fatigue</td>
<td>Fatigue</td>
<td>Operating</td>
<td>No</td>
<td>Note$^c$</td>
</tr>
</tbody>
</table>

**Notes:**

- Anisotropic materials may require special consideration.
- $^a$Use of $C_r$ is described in Section 5: strength issues are discussed in 5.2, deflections in 5.3, collapse issues in 5.4 and 5.5, fatigue in 5.6.
- $^b$Pipeline codes may require lower $C_r$ for risers that are part of a pipeline.
- $^c$Not applicable.
- $^d$Plant testing for rigid risers should be agreed between user and manufacturer.
DESIGN CONSIDERATIONS

• 3 ~ 1,000 YR HURRICANES
  – Within 12 MONTHS

• Primary Source of Damage
  – Wave Loading

• 100 Yr Hurricane ≤ 45 ft wave
• 1,000 Yr Hurricane ≥ 45 ft wave
IVAN THE TERRIBLE
HURRICANE IVAN

4000 Structures and 33,000 Miles of Pipeline in the Gulf of Mexico

150 Structures and 10,000 Miles of Pipeline in the direct path of Ivan
Ivan the Terrible
HURRICANE IVAN
Hurricane Katrina 2005
HURRICANE KATRINA

Deepwater Nautilus

- Rig Design: 5th Generation Deepwater RB8-8M
- Current Location Gulf of Mexico, GC 390
- Mooring type: 8 Point Mooring System
- Current Operator: Shell

Transocean
PO Box 2765
Houston, TX 77252-2765
Phone 713.232.7500
Rig Under Construction
Mars TLP

- Design to withstand 71 ft wave and 140 mph wind.
- Water depth 2940 ft.
- Block MC 807
- Current production 140000 bopd, 156 MMSCFD gas
- Installation 1996
- Operator: Shell
- Ownership: Shell 71.5% and BP 28.5%
Mars TLP (30 Aug 05)
U.S. Refining Capacity

- Still down after Katrina: 4%
- In the path of Rita: 21%
- All other: 75%

Source: EA, RJ est.