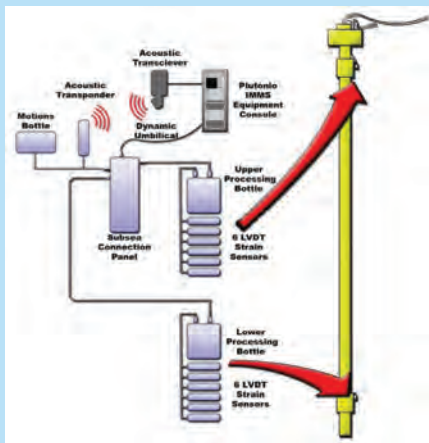
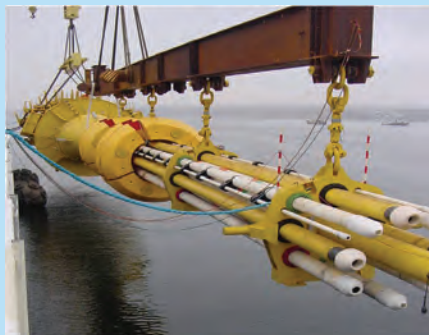


Hybrid Riser Tower Monitoring

Bundled hybrid risers are multiple risers supported by a central core pipe, offset from the Floating Production Storage and Offloading (FPSO) platform. BMT offers a comprehensive system for monitoring the integrity of bundled hybrid risers.



Simplified Block Diagram of HRTMS



Architecture of a Bundled Hybrid Riser - Central Core Pipe takes the load and carries no product

Hybrid Riser Tower Monitoring Systems (HRTMS) use remote subsea devices to assess degradation of buoyancy and bending fatigue. The main function of the HRTMS is to provide operators with a steady, long-term assessment of the buoyancy force that stabilizes the tower. Strain sensors are placed just below the tower top buoyancy module and optionally near the bottom of the tower on the riser core pipe. As a back-up to the strain sensing devices, relative position from the FPSO to the riser tower top and riser tower top static and dynamic inclination and lateral motions are measured with inertial sensors.

HRTMS Advantages

- Proven longevity: MTBF - 46 years
- Extremely low power
- Over 70 systems in service
- High resolution and accuracy

HRTMS Main Elements

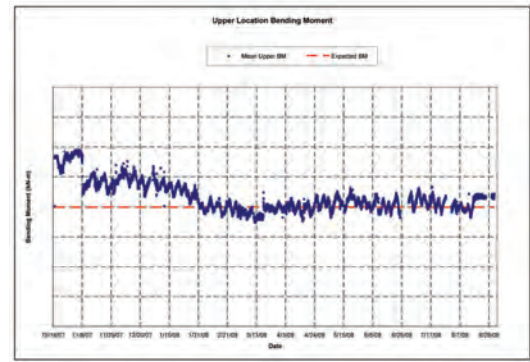
- Strain Sensors: 6 per location recommended (number based on redundancy requirements)
- Local Processing “Bottle” near each Sensor Station
- Separate Static and Dynamic Inclination and Motion Package on the Buoyancy Can Top
- USBL Transponder on Buoyancy Can
- USBL Transceiver on FPSO Hull
- PC Based Data Acquisition System on FPSO (employs BMT’s WINMON data archiving and display software)
- System Powering and Data Communications Options:
 - Hardwire (electrical) 2 TSP
 - Batteries/Acoustic Link

Additional Measurement Options

- Precision Depth Measurement of Tower Top
- LBL Based-Earth Fixed Tower Position

BMT SSSA Performance

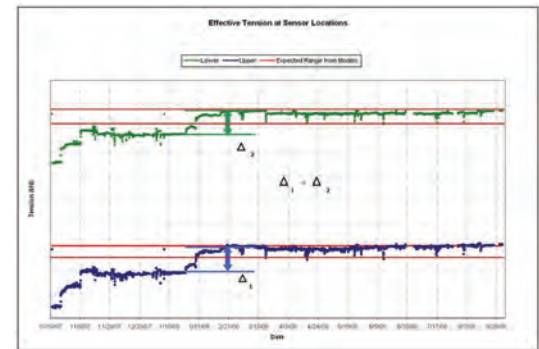
- Maximum Range: $\pm 3300 \mu\epsilon$
- Typical Full Scale Range: $\pm 600 \mu\epsilon$
- Accuracy: $< 1\%$ Full Scale
- Sensitivity: $< .25 \mu\epsilon$
- Long Term Drift (2 years): Negligible
- MTBF (single sensor): 400,000 hours
- Depth Rating: 2500 meters
- Power Requirement: 75 milliwatts per sensor



HRT Bending Moment (expected value from numerical model in red) vs. Time

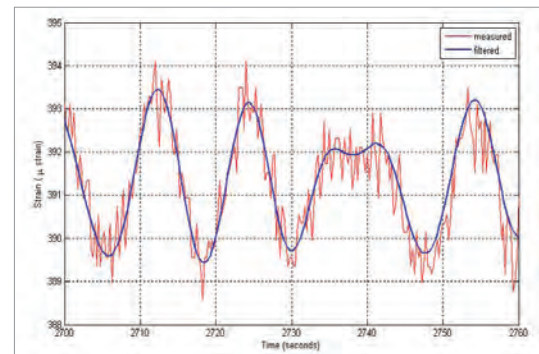
Long-Term Plot of Core Pipe Tension (illustrates long term stability)

- Measured tension agrees with expected values
- Upper and Lower change the same amount
- No drift

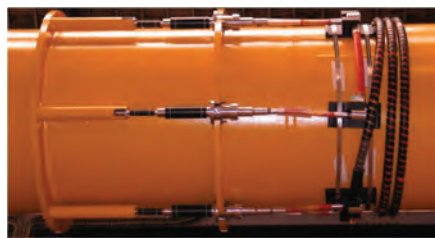


Strain Resolution Assessment (based upon full scale data taken under mild conditions)

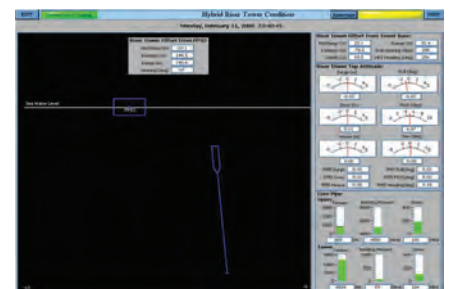
- BMT SSSA exhibits sensitivity that approaches that of a resistance strain gage
- BMT SSSA resolves $1 \mu\epsilon$ changes without filtering
- Resolution after filtering is less than $0.25 \mu\epsilon$



Subsea Strain Sensor



Strain Sensors as installed



Real Time User Display