FALMOUTH SCIENTIFIC INC.
INTEGRATED MONITORING SYSTEMS

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A. OVERVIEW FALMOUTH SCIENTIFIC, INC.

FSI operates from a state-of-the-art manufacturing facility on Cape Cod, Massachusetts. Our close proximity to many prestigious organizations such as the Woods Hole Oceanographic Institution, Massachusetts Institute of Technology, and NOAA, enables us to remain at the forefront of marine technology.

FSI's proven manufacturing processes and personnel have successfully fabricated, tested and delivered numerous sensor-based systems to customers around the world. Our quality program remains compliant with ISO 9001, which has led to excellent product reliability.

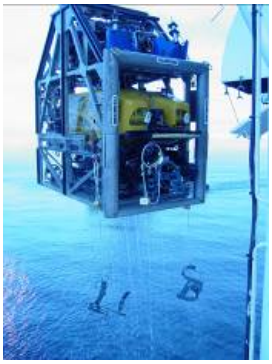
VORTEX-INDUCED VIBRATION MONITORING SYSTEMS

FSI's experience in deployment of remotely telemetered structural stress monitoring employing FSI (formerly Acoustikos) equipment began in 2002. UNOCAL first deployed a series of modem-enabled accelerometers down to 3000 meters on the SEDCO 601 in Indonesian waters. USS-110 Underwater Structural Stress monitors, designed by FSI and shown at right, included inputs from external strain gauges produced and installed by Mr. Norm Peterson of Electronic Measurement Co., along with a UCI-100 Underwater Camera Imaging system controlled from the ACU-100 Acoustic Command Unit topside. Installations of the USS-110 units were accomplished during riser deployment and were recovered along with the risers at the end of the well. Following a successful drilling program on the SEDCO 601, a duplicate system was employed on the Ocean Baroness in 2003 on behalf of UNOCAL. Again, the complete system incorporated a combination of accelerometers and camera system, shown right being readied for deployment via an ROV, for visual confirmation.

After several years of excellent results, UNOCAL turned to FSI to develop an ROV-deployed accelerometer logging system to measure vortex-induced vibration of TLP risers. Employed on the West Seno tension leg platform in 2004, these units were put in place for a long-term study of current- and vortex-induced motion of riser systems. Located in approximately 1000 meters of water in the Makassar Strait, off the coast of Indonesia, this area is characterized by strong and persistent ocean currents.

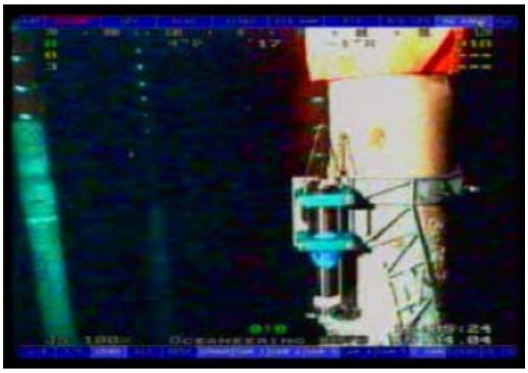
The result of this development at FSI was the compact Accelerometer Data Logger (ADL-536) shown at left. This lightweight unit was designed for long-term deployment studies. Deploying an array of these units, each equipped with its own high-accuracy clock, enabled engineers to perform post processing analysis of VIV data and compare it to ADCP data retrieved simultaneously through alternate means.

Key to this program was the ability to monitor risers already in place. An innovative clamping method was developed through a consortium of FSI, UNOCAL and Mr. Norm Peterson of Electronic Measurement Co. This new clamp allowed easy ROV installation of the instruments on the riser pipe.



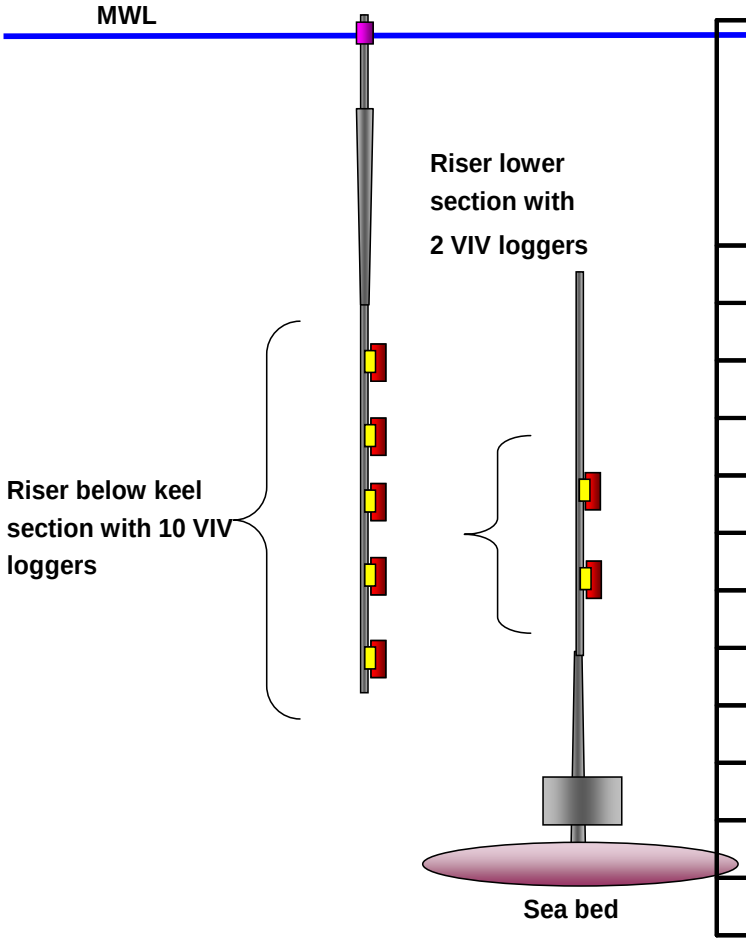
Once set in place by the ROV, the logger acquires data until time for retrieval. At the end of the logging period, the clamps and loggers are retrieved by the ROV and brought on board for data recovery and battery refreshment. Multiple ADL-536s were ferried to the deployment locations in baskets on top of the ROV cage.

A series of 10 accelerometer loggers were deployed on a single riser during a logging period. In addition to 10 subsea units as shown below, a surface unit was placed on the rig just above the tensioner for the riser depicted at right.



Following is a schematic and layout of a typical instrument deployment

ACCELEROMETER PLACEMENT
West Seno TLP-A

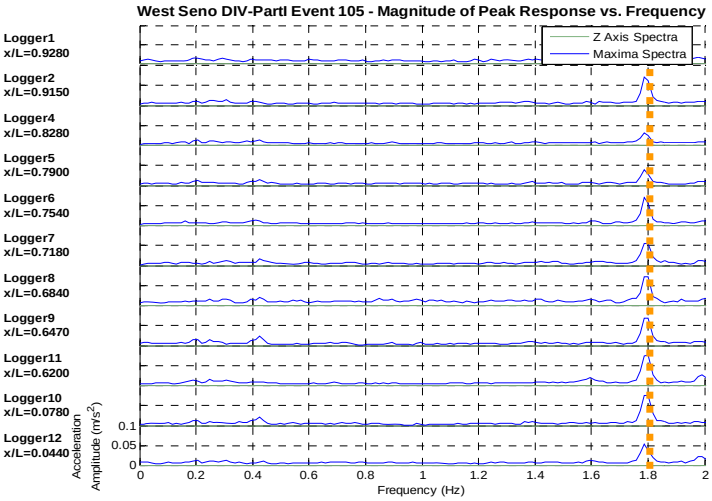


Logger ID	Depth below MWL – Planned (ft)	Depth below MWL – Deployed (ft)	Logger Spacing (ft)
L1	174.75	203	-
L2	294.75	323	120
L3	414.75	450	127
L4	534.75	574	124
L5	654.75	701	127
L6	774.75	788	87
L7	894.75	915	127
L8	1014.75	1041	126
L9	1134.75	1170	129
L10	1254.75	3091	-
L11	3136.75	1258	88
L12	3256.75	3214	123

Data recovered was post-processed for DIV, VIV and spectral analysis.

Example Data: Drilling-Induced Vibration

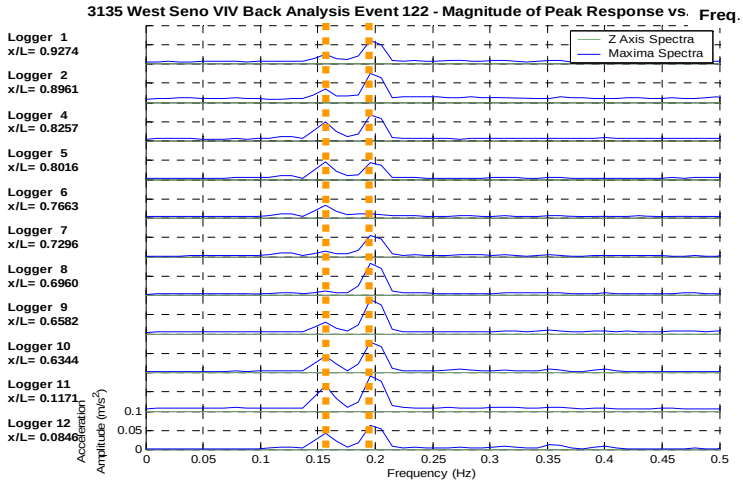
- **Spectral Peak at 1.8 Hertz**
- **In the range of drilling RPM**
- **Some variation of amplitude with depth**



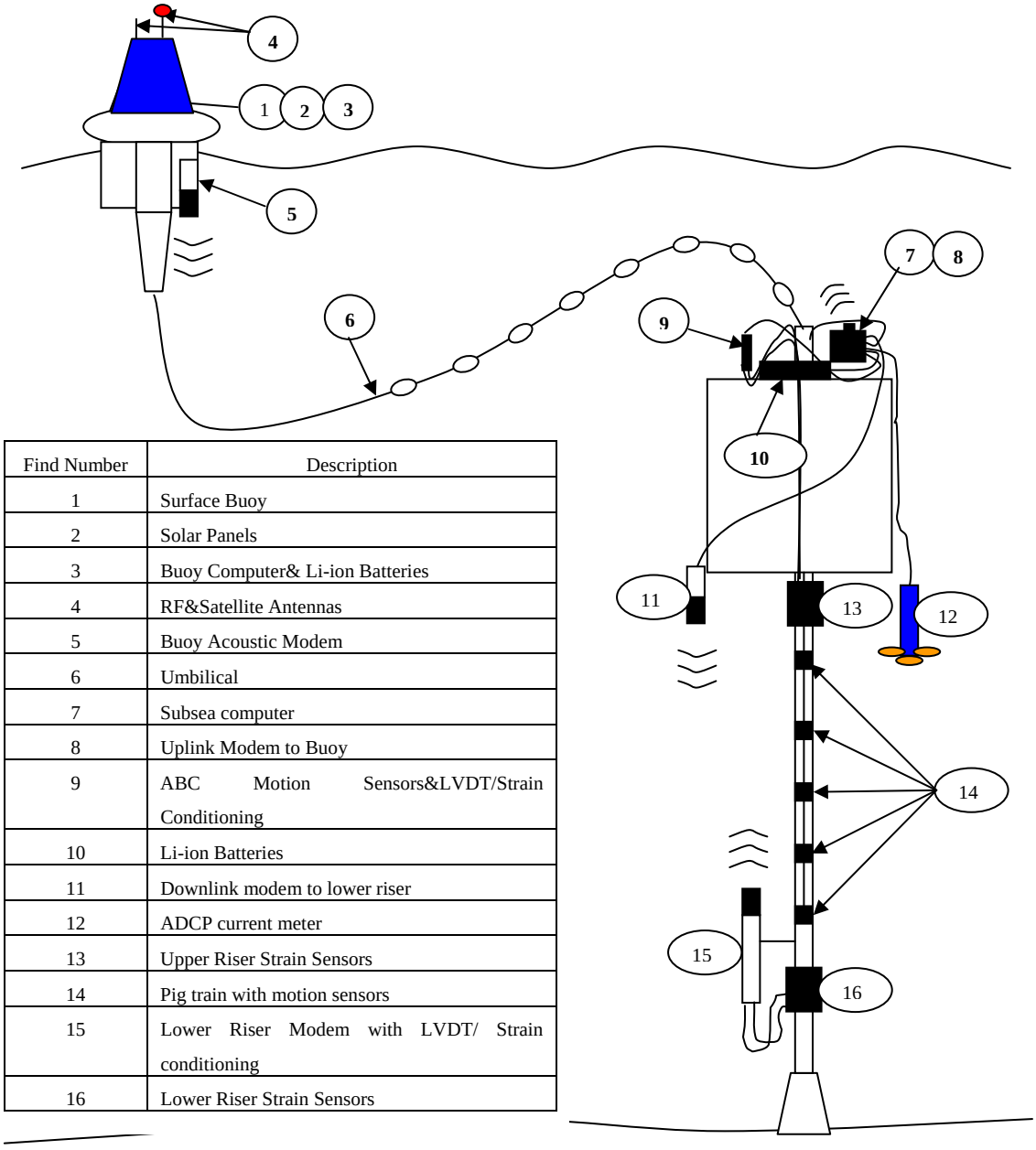
In conjunction with UNOCAL, FSI has developed the USS-540 system as an integrated system combining the real-time telemetry and third-party sensor input of the USS-110 with the acceleration and inclination measuring of the ADL-536.

Example Data – Vortex-Induced Vibration

- **Spectral Peaks at about 0.16 and 0.19 Hertz**
- **Distinct variation of amplitude with depth – nodes and anti-nodes**



ANADARKO REAL-TIME RISER MONITORING SYSTEM



Find Number	Description
1	Surface Buoy
2	Solar Panels
3	Buoy Computer& Li-ion Batteries
4	RF&Satellite Antennas
5	Buoy Acoustic Modem
6	Umbilical
7	Subsea computer
8	Uplink Modem to Buoy
9	ABC Motion Sensors&LVDT/Strain Conditioning
10	Li-ion Batteries
11	Downlink modem to lower riser
12	ADCP current meter
13	Upper Riser Strain Sensors
14	Pig train with motion sensors
15	Lower Riser Modem with LVDT/ Strain conditioning
16	Lower Riser Strain Sensors

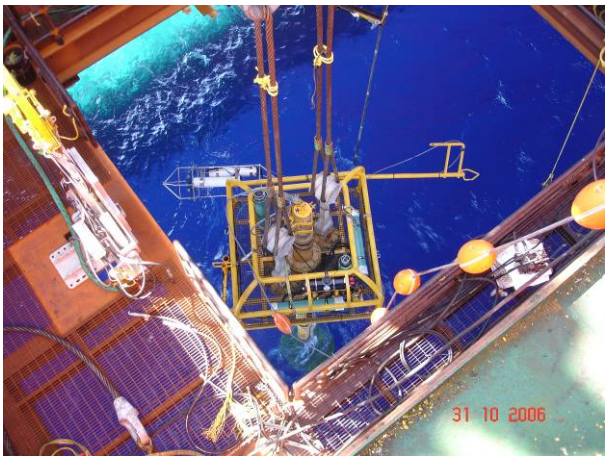
Figure 1- PI-921 Riser Monitoring System

A real-time riser monitoring system supplied to Anadarko consisted of 8 main sections:

1) The surface buoy which contains the buoy computer, solar panels, surface batteries, iridium satellite & 900MHz RF data modems, buoy acoustic modem, and umbilical cable (items 1 – 6).
2) The subsea computer with uplink & downlink acoustic modems (items 7, 8&11).
3) The ABC motion sensors with upper riser LVDT/Strain gage conditioning (item9).
4) The subsea Li-Ion batteries (item10).
5) The ADCP (Acoustic Doppler Current Meter) (item 12).
6) The upper riser strain sensors (items 13).
7) The riser motion sensor pig train (item 14).
8) And the lower riser modem with strain conditioning and lower riser strain sensors (items 15&16).

The lower riser instruments measure the stress of the riser above the tie back connector using resistive strain gages and inductive LVDTs. The strain and LVDT signals are conditioned, sampled and transmitted to the ABC computer via an acoustic modem. The upper riser strain and LVDT sensors measure the riser stress just below the ABC module. These sensors are connected to a conditioning module which transmits the sampled data to the ABC computer via the RS485 bus. The pig train motion sensors are provided to sample acceleration and inclination, at intervals, along the riser from just below the ABC down to near the mud line. The 3-axis acceleration and 2-axis inclination data sampled at the five pig train locations are transmitted to the ABC computer by way of the RS-485 bus. The ABC motion sensors are contained in the upper riser sensor conditioning module, they include the 3-axis acceleration and 2-axis inclination of the ABC along with a pressure transducer which will provide a measurement of the ABC set down.

The computer located on the ABC samples and stores the raw data from all the system sensors. Periodically, the sensor data is transferred to the surface buoy computer, via Ethernet connection, where it is forwarded to shore through the iridium satellite network. The data is collected on the shore based server computer and made available for downloading via a password-protected FTP site.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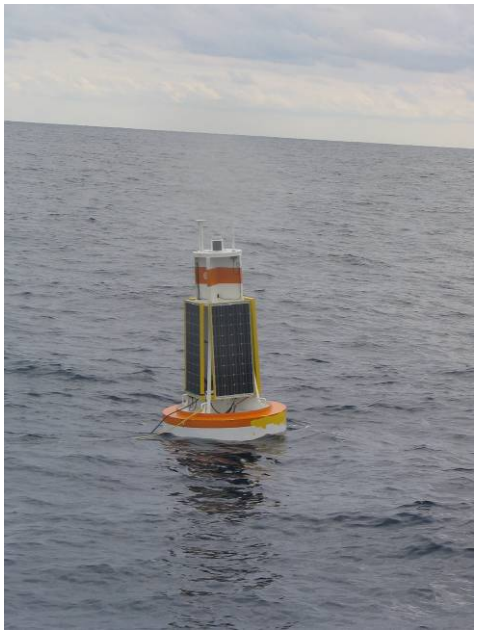

FSI
Example Monitoring System Diagram