MEMS - A Real-Time Port Monitoring System

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SUMMARY The paper describes the specification of a Mooring Load and Environmental Monitoring System (MEMS) to continuously monitor and display real-time mooring load, atmospheric and ocean conditions at Woodside Offshore Petroleum's LNG and condensate processing and loading facility in North-West Australia. The system also records selected data under conditions causing specified threshold values to be exceeded.

1. INTRODUCTION

As operator for a joint venture, Woodside Offshore Petroleum (Woodside) is developing gas and liquid hydrocarbon deposits off Dampier, WA. The first production platform, North Rankin 'A', has been supplying natural gas and condensate since 1984.

However, the major market for the development is the sale of liquefied natural gas (LNG) to Japan. To achieve this, the natural gas piped ashore from North Rankin 'A' is liquefied at an onshore processing plant and subsequently loaded into LNG tankers for shipment.

Prior to the first LNG shipment, scheduled for the third quarter of 1989, an on-line data acquisition system was installed to continuously monitor mooring load, atmospheric and ocean conditions at the processing and loading facilities, replacing a temporary system which has been in operation since 1983.

The system, termed the Mooring Load and Environmental Monitoring System (MEMS), will be used primarily as a port management tool, assisting tanker berthing, loading and departure, and to enhance safety margins.

This paper presents the requirements and specification of the MEMS.

2. REQUIREMENTS

The major location for data acquisition is the LNG and condensate loading facility, comprising a Jetty and Dolphin Berth, adjacent to an onshore processing Plant in Mermaid Sound (Figure 1).

By 1993 the facility will be handling 104 LNG shipments of 125,000 m^3 each and approximately 80 shipments of condensate, averaging 45,000 tonnes, annually.

Prior to berthing, the tankers (up to 300m long) must turn their full length in a 600m turning basin adjacent to the Jetty. Knowledge of the wind, current and wave conditions in the vicinity of the Jetty is thus essential for safe and efficient berthing.

The vessel is then berthed at the Dolphin Berth which consists of 6 mooring dolphins and 6 breasting dolphins. Each mooring dolphin has a triple, and each breasting dolphin has a double, quick-release hook assembly available, and the number of hooks used varies, depending on vessel size.

During product loading, continuous monitoring of the loads on mooring lines is required to ensure a minimum line tension, and also to avoid excessive loads on the mooring system (lines and dolphins). Winds, waves and currents also affect the vessel while at berth and need to be monitored.

The length of the tankers makes them susceptible to longer period waves, even of relatively small amplitude. These waves, undetectable by an observer, need to be monitored and early warning

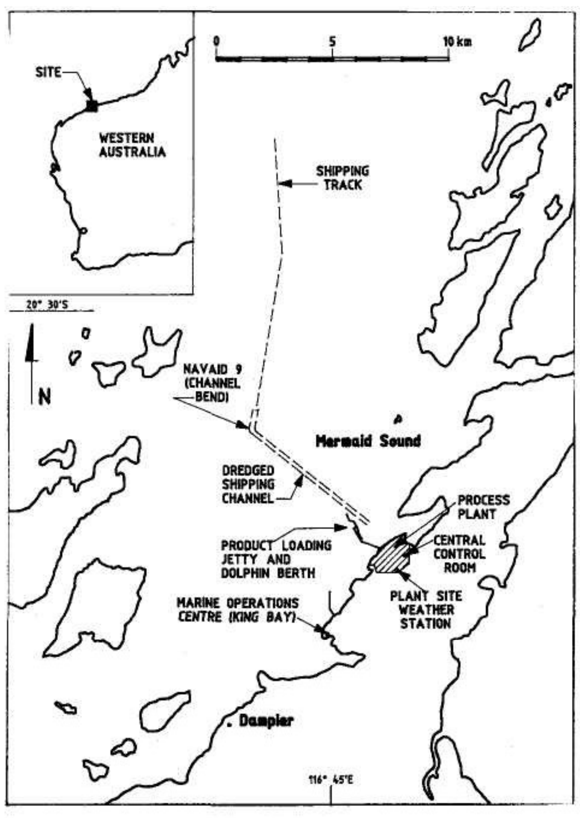

Figure 1 : MEMS location plan

of their arrival provided to give the tanker sufficient time to stop loading, depart and clear the channel before critical conditions develop.

In the case of product spillage or unplanned release, information on atmospheric and ocean conditions is needed as input to emergency operations. Real-time atmospheric data at the onshore processing Plant are required for the same application.

An important aspect of a vessel navigating into the Jetty is the negotiation of the shipping channel (Figure 1). Data on current and wave conditions are required by the Pilot.

In addition to the real-time monitoring requirements, recording of simultaneous mooring load and environmental conditions is needed in order to verify results of studies of moored vessel responses and berth operability, and to assess and revise operational procedures. Recorded environmental data also form an essential part of future design and operation applications.

The real-time data is required for display at several locations. In transit to the Jetty and while berthing, the tankers communicate with the port via Woodside's marine operations communications centre located at King Bay, 4km from the Jetty (Figure 1), and receive information on conditions at the Jetty during this process.

Once berthing is completed, product loading is monitored by a Central Control Room (CCR) located onshore, 2km from the Jetty (Figure 1). Data on mooring loads and environmental conditions comprise some of the many inputs required at the CCR, as well as being required on board the tanker.

The data is also required in Perth, 1600km South, to enable Woodside's Ocean Engineering group to monitor atmospheric and ocean data quality, and for use by Woodside's marine operations group, Mermaid Sound Port and Marine Services Pty Ltd.

All of the above requirements need to be satisfied in the context of a harsh tropical, coastal marine environment, subject to tropical cyclone activity between November and April. Tropical cyclones generate the most severe winds, sea state, tidal surges and heaviest rainfall in the area, but are infrequent (varying from zero to six in any season) and are within 100km of the loading facilities for only about two weeks per year. Winter storms may also produce conditions which affect operations. For most of the year, however, the climate is hot and humid, with little rain.

In additional to the usual effects of a marine environment, a high percentage of airborne salt and iron ore dust in the atmosphere from nearby stockpiles at Dampier, together with accelerated marine growth from high water temperatures, severely tests equipment reliability.

3. SPECIFICATION

The challenge was, therefore, to specify a system which would meet all of these diverse requirements, and would operate reliably in the extreme environmental conditions in the area.

3.1 Signal Transmission

The first major problem, given the physical separation of the various measurement and display locations (Figure 1), was the means of transmission of raw input data. Radio transmission has been found to be unreliable in the area, especially during the high winds and torrential rain associated with tropical cyclones, but transmission via standard electrical cable over the distances involved also has limitations.

Fibre optic cable had already been selected to link the CCR with the Plant and the loading facility on the Jetty, but did not extend to the Dolphin Berth, 7m below the Jetty, nor to the site adjacent to the Plant where atmospheric parameters were to be measured.

Since the Plant measurement site is situated only 1km from the CCR, a standard 2-pair cable link was chosen. A similar link was selected, considering the relatively short distance involved, to carry the signals from the 30 mooring hooks and atmospheric and ocean data measurement instruments on the Dolphin Berth to an equipment building on the Jetty, thence by way of a fibre optic link to the CCR.

However, in the case of data transmission from the channel bend, 6km from the Jetty and 8km from the CCR, a radio link was the only feasible option in view of the expense and maintenance problems associated with a sub-sea cable link.

3.2 Instrumentation

3.2.1 Jetty Waves and

Currents

A common method used to monitor wave and current conditions is by means of a moored wave buoy, such as a Waverider, in tandem with a current meter on a separate mooring. If wave direction is also required, a directional buoy such as a WAVEC would be substituted, with the resulting increase in buoy diameter from 0.7m to 2m. However, in this instance an alternative to moored instruments was preferred for a number of reasons: maintenance of moored instruments requires a boat, which limits servicing due to weather, seastate and boat availability; data transmission by radio, as noted previously, is not always reliable; and surface buoys in the nearshore area can pose navigational problems, particularly if they drift during extreme conditions.

Consequently, a subsea instrument suspended from the Dolphin Berth was specified, comprising pressure, current velocity and water temperature sensors. Directional wave data may then be derived from simultaneous pressure and velocity readings. There are disadvantages with this option, primarily the attenuation of higher frequency wave data resulting from use of a pressure sensor, and the effects of structural interference from nearby piles and dolphins. The quality of wave direction estimates compared to a surface buoy may also be questioned.

However, service access is significantly improved, with other benefits, such as transmission of data via cable and the ability to fix the unit both horizontally and vertically, enabling tide height measurements relative to a fixed datum and reducing degradation of wave and current data due to instrument motion.

Winds

In view of sheltering caused by the LNG tanker superstructure (30m above the sea surface) and the LNG loading mechanism, the Jetty anemometer needed to be located some distance above and away from these effects.

The eventual location selected was on a 4.5m high tower atop an equipment building on the jetty, approximately 32m above sea level, subjecting the instrument to 25% stronger wind speeds than at standard 10m height.

Mooring Loads

Mooring loads were specified to be measured by means of a load sensor pin, replacing the swivel pin at the rear of each hook.

3.2.2 Channel Bend

A moored buoy was even less desirable at the Channel Bend location, 6km offshore from the Jetty, than at the Dolphin Berth, since the serviceability, transmission and navigational hazard problems are magnified, so a subsea pressure/velocity/temperature unit was again specified. Navaid 9, one of a group of three navigational beacons at the Bend (Figure 1), was chosen as the attachment point, the maintenance benefits of a single unit were more apparent at this remote location, but data transmission by radio and the need for servicing by boat are unavoidable aspects.

3.2.3 Plant

A temporary meteorological station has been in operation on the Plant site since 1983, recording and displaying all the parameters required for the present application: wind speed and direction, air temperature, relative humidity, barometric pressure, solar radiation, rainfall and evaporation. A number of aspects needed to be addressed for a permanent installation, however, including upgrading of instruments and cabling, automation of evaporation measurements, housing of sampling and transmission equipment, and site layout.

3.2.4 Other Considerations

Due to safety zoning classifications, all instrumentation at the Jetty/Dolphin Berth facility was required to be intrinsically safe. This necessitated the addition of Zener barriers, and restricted the range of instruments available to meet accuracy, resolution and operating range requirements, especially for measurement of extreme conditions.

3.3 Data Processing

Having established the data measurement aspects of the system, attention turned to data processing.

All input signals were specified to be continuously sampled at 2Hz, in order to give sufficient resolution for subsequent analysis. Although some parameters do not need to be sampled at such a high rate, it was judged to be more efficient to specify a single sampling rate.

3.3.1 Mooring Loads

Mooring loads on each hook in use were required as 3-second and 1-minute averages, as well as the maximum and minimum 3-second mooring load over the previous minute.

3.3.2 Waves

Following conversion from pressure to surface elevation, and pre-processing filtering and de-trending, both time domain and frequency domain analyses were specified to give standard wave height and period parameters. The same frequency domain parameters were specified to be calculated for locally generated wind waves (sea), swell and long period waves (>20s) by dividing the frequency range into three sub-ranges: f>0.125Hz, f between 0.125Hz and 0.05Hz and f<0.05Hz, respectively. Calculations of wave parameters were then to be repeated on the energy in each of the three sub-ranges.

Mean wave direction, directional spread and linearity index, as described by Forristall et al (1978), were also specified to be calculated for total, sea, swell and long period waves, to be derived from simultaneous pressure and current velocity component data.

3.3.3 Currents

The current velocity components were specified to be provided as 1-minute vector-averaged speed and direction.

3.3.4 Winds

The specification for wind speed and direction called for 10-minute, 1-minute and 3-second (gust) vector averages, together with maximum 3-second gust over the previous minute, and standard deviation of wind direction associated with the 10-minute mean.

3.3.5 Other

The remaining atmospheric measurements, plus water temperature and tide height, were specified to be processed as 10-minute means.

3.4 Recording

In order to satisfy recorded data requirements, all processed data were specified to be transferred to a mass storage medium, such as a cartridge tape. To minimise inter-record gaps on the tapes, processed data for the previous 20 minutes were to be transferred to the storage medium every 20 minutes. In the event of recording unit failure, provision has been made for data to be stored for up to 24 hours.

Selected 2Hz data from all active mooring hooks, wave/current and wind sensors were specified to be stored in 1-minute ring buffers so that, if the system were to be triggered by one or more values exceeding pre-set levels, information immediately preceding the event would be recorded. Recording of the 2Hz data would then continue until all values returned to their normal operating range.

With all values within alarm limits, 2Hz values were specified to be recorded every 3 hours, with the exception of mooring load data, which would not be recorded if there were no tankers at the Dolphin Berth.

Provision was to be made for the 2Hz data to be stored for up to 1 hour in case of recorder failure.

As there would normally be approximately 1 month between tape changes, regular transmission of processed data (calculating period of 1 minute or longer) to Woodside's Perth computing system was specified. This feature was also designed to enable: the timely identification of errors not readily evident from the monitoring of displays and trends; availability for rapid response to Woodside data needs; and backup in the case of recording unit malfunction.

3.5 Display

In addition to the primary operational display location in the CCR, data displays were also required operationally at the King Bay Radio Room and on board the berthed tankers and, for monitoring purposes, at two locations in Perth. The displays themselves were specified to comprise digital and graphic displays of real time data, trends of historical data from the 24-hour database and a predictive capability based on extrapolation of a model fit to the historical data.

This last feature was intended primarily as a temporary measure until a planned Remote Offshore Warning System (ROWS) becomes operational. The ROWS will then provide predicted wind and sea state conditions to the MEMS which are beyond the capability of a simple extrapolated trend to forecast.

3.6 MEMS Computer

One of the earliest (and most debated) decisions pertained to the degree of centralisation of data processing. Advice was taken that the data transmission links, particularly via fibre optic cable, were sufficiently reliable that data sampled at each site could be safely directed to a central location for processing and recording. (The Navaid 9 radio link was a subsequent requirement).

This decision required the central computer to check and process the incoming data from all 49 sensors over periods varying from 3 seconds to 3 hours, in addition to: servicing display requests within 5 seconds from up to 5 units independently, including trend analyses; transferring data to tape every 20 minutes and to Perth less frequently; accepting data from the ROWS; and continually checking processed parameters against pre-set alarm and warning levels.

The system was also required to check each input signal against specified rate-of-change and range limits, and flag any occurrences outside those limits.

3.7 Other Features

3.7.1 Fault Logging

In view of the complexity of the system in terms of different sensors and widespread locations, a self-diagnosing and automatic logging capability was essential. The specification called for monitoring of all sensors, power supplies, transmission links, display and recording units, including remaining tape capacity, and the CPU itself, as well as the warning and alarm levels, and rate-of-change and range limits, mentioned previously.

Any occurrence of a malfunction or limit transgression was specified to be written to a log file, together with time, date and any other relevant information, such as limit value, and a useful diagnostic message. All actions on the system, whether operator-activated or automatic, were also required to be logged.

3.7.2 System Modes

Another consideration revolved around the monitoring of mooring load data. When a tanker is berthed, the requirements are straight forward: all hooks are monitored and alarm and warning levels set. The first problem arises just prior to this, when the tanker has arrived at the Berth and mooring lines are being attached to as many as 16 hooks. During this process, termed pre-tensioning, one or more lines may be slack, which would trigger an alarm if it occurred while the tanker was loading. Hence, mooring load alarms need to be disabled until the lines are suitably tensioned, while the system still monitors environmental conditions and processes the mooring loads. Similar requirements apply when the tanker is preparing to depart the Berth and mooring lines are being cast off.

The system will normally be changed into pre-tensioning or departing modes by an operator on advice from the appropriate person on board the tanker. However, provision was also made for the system to automatically select pre-tensioning mode as soon as any of the 30 hooks measure a tension higher than a pre-set limit.

Once the tanker is berthed, mooring load alarms will be re-activated. Again, this mode will normally be selected by an operator, but can automatically be selected when the loads on all pre-selected hooks are within a pre-set limit range. Similarly, once the tanker has departed, mooring loads will no longer be calculated, and alarms on mooring loads will be inhibited. This mode has been specified to be automatically selected when the loads on all hooks are lower than the pre-set limit for longer than five minutes, although this period is able to be varied based on operational experience.

Ocean and atmospheric data calculations and alarms will be active continuously.

3.7.3 Software Development

In order to be able to carry out software maintenance and enhancements, a software development environment was specified which would enable changes to the relevant module to be made, debugged and tested, initially by using trial data sets with known input and output, then by use of real-time data. The ability to test the modified software with actual data before making it available in the real-time system is essential, since a bug which does not show up in an artificial test situation could bring the real-time system down when installed, possibly at a critical time.

This software development environment was specified to operate without interference to the real-time system so that, for example, a program compilation would not slow the real-time system down to a point where it did not have sufficient time to carry out critical operations.

4. SUMMARY

The MEMS as specified satisfies the requirements listed in Section 2, providing both real-time information for the loading of LNG and condensate tankers, and recorded data for associated applications.

To give some idea of the demands on the system, the requirements necessitate continuous 2 Hz sampling of 49 input signals (nearly 6000 samples per minute) from 30 mooring hooks and 10 atmospheric/ocean instruments, in 17 locations at 4 separate sites spread over 10km (Figure 1).

In addition to then carrying out the data processing detailed in Section 3.3, the MEMS must continuously monitor the rate of change of every parameter - some 450 of them - against pre-set tolerances, and also monitor each sensor, power supply, output unit (display units, printers, processors and tape units), communication links and input from other sources, such as the ROWS and North Rankin 'A'.

All of the parameters must then be available for further analyses (such as trending) and be able to be independently displayed at 5 individual locations almost immediately (within 5 seconds of a request), transferred to cartridge *every* 20 minutes and transmitted 1600km to Perth at regular intervals.

5. IMPLEMENTATION

The system specification was implemented and installed by a Western Australian engineering company, ACET Ltd, sub-contracting to Sydney-based coastal and ocean engineers, Lawson and Treloar Pty Ltd, and UK mooring load monitoring specialists Strainstall Ltd, who hold Australian patents for such work.

The instrumentation selected to satisfy the specified requirements comprised Sea Data 624XP directional wave/current meters, ACET 7330AB anemometers and various atmospheric sensors including Vaisala (temperature/humidity and pressure), Rimco (rainfall), Haenni (solar radiation) and Qualimetric (evaporation).

The instrumented mooring load pins were manufactured by Strainstall Ltd.

6. CONCLUSION

Although the requirements for the MEMS are not beyond the scope of present-day computers and instrument systems, their diversity and physical separation, coupled with a harsh operating environment, resulted in a unique specification.

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