Risk Management of Moored Mobile Offshore Drilling Units in the Western Pacific Ocean

Evan H. Zimmerman & Daniel J. Alonso
Delmar Systems, Inc.
2424 Wilcrest, Suite 225
Houston, Texas 77042 USA

***Abstract*- The significant number of Moored Mobil Offshore Drilling Units (MODUs) that lost station in hurricanes Ivan, Katrina, and Rita has resulted in changes in the way offshore deepwater drilling risk is managed. Risk assessment is now a requirement for temporary MODU moorings operating on the United States' Outer Continental Shelf (OCS). The nature of such operations does not allow for long lead-time assessment and thus requires a rapid method to allow for timely well planning, equipment management and permit approval. This paper will outline a now commonly used process of assessing site-specific risk of operating a moored MODU on a wide variety of current offshore locations in the US Gulf of Mexico and draw insight to implementing similar processes to the Western Pacific Ocean.**

I. Introduction

Risk is the product of both probability and consequence. When considering moored MODU risk, the challenge mainly lies with determination of both the value of actual consequences of MODU mooring failure and being able to predict a reasonable probability of such a mooring failure that would produce each particular consequence. By evaluating potentially thousands of different risk events and sorting them based on risk level, one can focus in on the key risk drivers for each location and can more effectively manage the risk.

Risk Assessment Approach

After the study of multiple Moored MODU failures, the risk components were gathered and evaluated. The influence of each was estimated based on industry experience and post failure analysis.

Probability was tackled by first addressing at which line tension factors of safety mooring failure actually began. For this, multiple full reliability analyses were utilized to calibrate an easy and fast method of evaluating the controlling probability of mooring lines to begin breaking based on an intact mooring system's line tension factor of safety of 1.2. From that point, multiple event trees splinter off and based on equipment and site conditions, the different probabilities of mooring component dragging, anchor dragging, and the damage associated with both, can be accounted for.

Consequence of each risk event is split into two main categories. The first is the cost of repair and the second is the differed or interrupted production value. Cost of repair was estimated based on realistic but upper bound repair costs provided by operators [1]. Repair costs were broken up into sub categories for different structures and pipelines as well as if the damage was minor or major. Differed or interrupted production was made possible once a detailed model of production was developed that tracked oil and gas flow from offshore platforms to the beach. Options for input production flow rates are also possible for areas where a production matrix is not automated yet. Production value uses a 3-year projection for average pricing for oil and gas.

II. Gulf of Mexico Experience

A. 2004 and 2005 Hurricane Season

Hurricanes Ivan in 2004, Katrina and Rita in 2005 created a total of more than 23 moored MODU failures. These failures quickly lead to significant regulatory and industry pressure to change the way moored MODUs are handled during hurricane season. A majority of the fleet was built under the first edition of the API RP 2SK and was designed to meet a 10-year hurricane, which was a minimum category 1 (64-knot 1-minute wind) storm.

While it was no surprise that these three huge storms produced so many mooring failures. It created a need to rethink the way moored MODUs are assessed such that all practical measures are taken to reduce interruption of the Oil and Gas flow from the Outer Continental Self (OCS) to the United States. Such interruptions in the wake of these storms affected all domestic prices and brought national attention to offshore industry.

Initial assumptions were that if a moored MODU failed, it would pull and drag its anchors to shore, tearing up pipelines along the way. Extreme concern focused in on moored MODUs rather than jack-up or DP units in the wake of the hurricanes. This focus generated support of the more than $2.5million US dollar MODU Mooring JIP [2] run by ABS Consulting. This JIP served as the basis for many of the new changes in the assessment practice and understanding of moored MODUs in the Gulf.

B. Changes in Design Code and Regulatory Approval

The American Petroleum Institute (API) quickly assembled a task group together to address a new interim guidance document that would take the initial learnings from the hurricanes and quickly get them out to industry to affect some increase in reliability if possible. In 2006, the first edition of API 95F was issued which contains initial guidance on mooring MODUs in the Gulf of Mexico during hurricane season. It was also in 2006 when the US Department of Interior's Minerals Management Service (MMS) started doing detailed reviews of mooring for MODU location permits. MMS began to evaluate risk of each moored installation and in

978-1-4244-5222-4/10/$26.00

some cases required the operators to improve moorings of the MODU or limited their ability to drill during hurricane season.

2007 brought a second addition of API 95F and continued MMS review of each location permit during hurricane season. In 2008, a new appendix K to API's station keeping document, RP 2SK, was released. This appendix covered a more complete collection of guidance for operating moored MODUs in the Gulf during hurricane season.

C. Rapid Risk Assessment

There are more than 50 moored MODU locations installed every hurricane season on the OCS. And there are more than 100 location assessments evaluated each hurricane season, so it becomes critical that an efficient, detailed, and accurate risk assessment be possible for each. This assessment routine accomplishes this and can typically be completed within a week.

D. Risk Drivers

Experience in the Gulf of Mexico has shown the main risk drivers, as expected, are anchors, strength of the mooring system, and proximity to major producing assets. Also as expected, the use of low pull-out risk anchors can drastically reduce the overall risk of the installation, only leaving collision risk as the driving events (which are usually small).

Fig. 1 illustrates the summary of all approved locations that utilized this risk assessment method during the 2008 hurricane season. This figure shows that the locations in the central Gulf, where metocean is more severe, the MODU line tension return periods of design are less. It also shows that locations in the central Gulf are higher risk generally and that is due to the proximity to multiple large producing assets. It is also apparent that a majority of the higher risk locations utilize less risky anchors to mitigate driving risk events to gain MMS approval.

In 2008, the Gulf saw both *Hurricane Gustav* and *Hurricane Ike*, which caused multiple mooring failure events. This time, there were no reported damage events as a result even though two of the MODUs went adrift. This was interpreted as a significant achievement since it indicated the new measures and risk assessment processes were working.

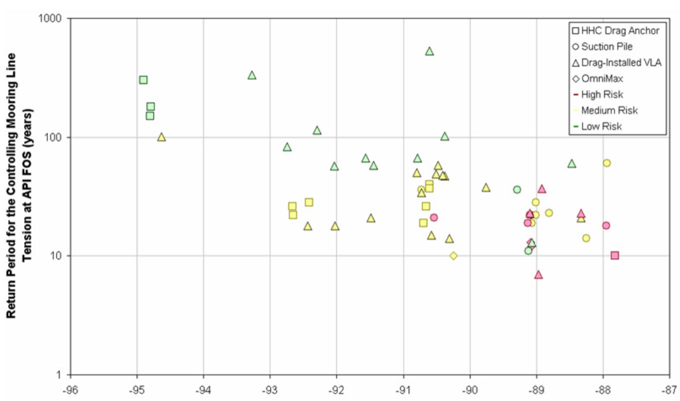

Figure 1. 2008 US Gulf OCS Moored MODU Risk Summary

One of the mooring failure events was the Transocean *Amirante* in *Hurricane Gustav* [3] which utilized OMNI-Max anchors to mitigate nearby risk events. The *Amirante* failed 7 of its 8 mooring lines and was left hanging onto location with its last mooring line and anchor. This performance illustrated the benefit of low risk anchors and increased survivability of such technology.

Fig. 2 illustrates the summary risk data for the 2009 season risk. Here again the same trends are shown among all of the locations. And again it is seen how anchors are a key mitigating measure operators utilize to reduce overall risk and gain location approval from the MMS.

Seasonality of the hurricane season is also a dominating driver on the US OCS. The most intense and frequent storms occur during the months of August, September and October. This risk assessment process includes the effect of this seasonality by way of a full hurricane database for the region. This allows for calculation of the location site-specific seasonality for each analysis. This also enables a single full year mooring analysis set of results to give a complete hurricane season risk picture.

III. Application to Western Pacific Ocean

The same moored MODUs operate around the world and the same mooring technology is also largely utilized on a global basis. Thus application of the same risk assessment methodology is not overly difficult to moored MODU locations in the Western Pacific Ocean.

A. Metocean

First, the location must be understood. This means that the metocean in the Western Pacific Ocean must be studied and understood.

The first challenge was to develop a similar typhoon database to the one already developed for the Gulf of Mexico. In doing so, four areas have been evaluated in offshore Australia: the Carnarvon, Browse, Bonaparte 1 and Bonaparte 2 regions. The same hurricane/typhoon modeler was utilized to develop a 24-year database of typhoons in these regions. Fig. 3 illustrates the relative difference between the 10-year and 100-year wind speed values of the four regions.

This indicates that the severity of winds in the Western Pacific is similar to that of the Gulf of Mexico. While only one location in each region was studied, the data indicates similar increases in intensity with return period as well. This all leads to confirmation that reliability of moored MODUs should be similar given the same robustness as in the Gulf of Mexico. Figures 4, 5, 6 and 7 illustrate the tracks and severity of the typhoons in the four regions studied since 1985.

Both the Browse and Carnarvon regions show significantly more typhoon activity than the Bonaparte regions. This activity also indicates that there may be sub-regions with greater intensity, activity and directionality. Those opportunities to sharpen the pencil and provide more insight to a risk assessment should be worth the investment.

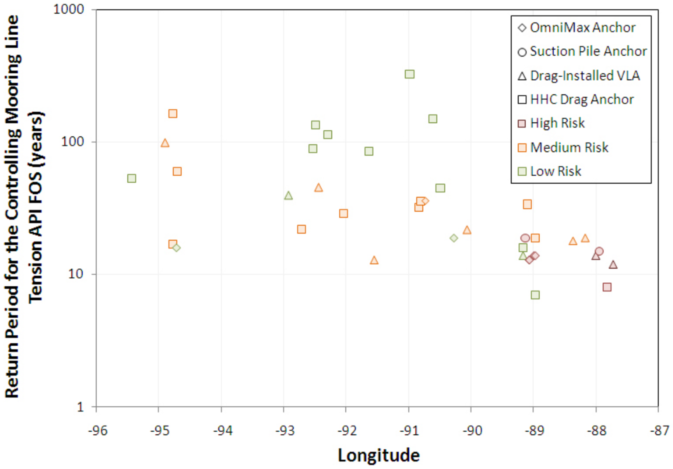

Figure 2. 2009 US Gulf OCS Moored MODU Risk Summary.

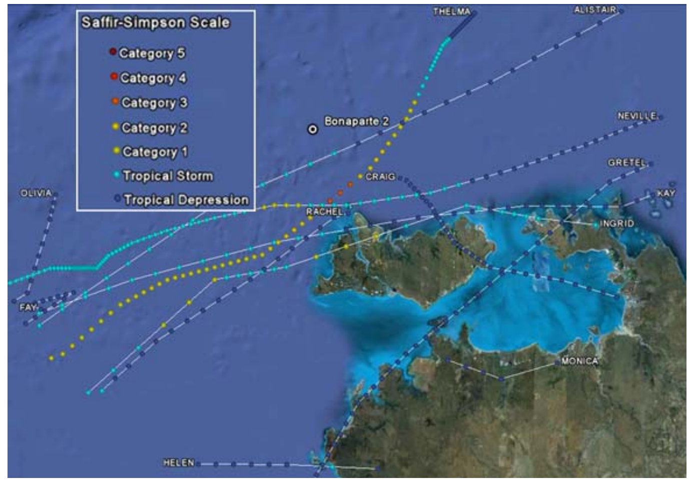

Figure 5. Hurricane Track and Severity in the Bonaparte 2 Region.

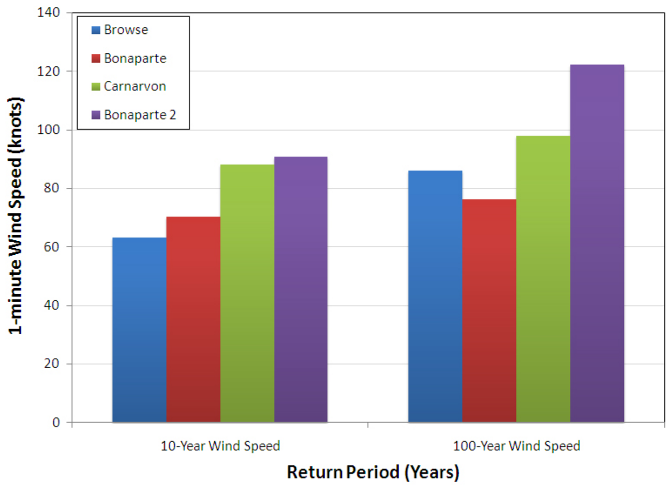

Figure 3. Comparison of 10 and 100-year Winds for Four Australian Regions.

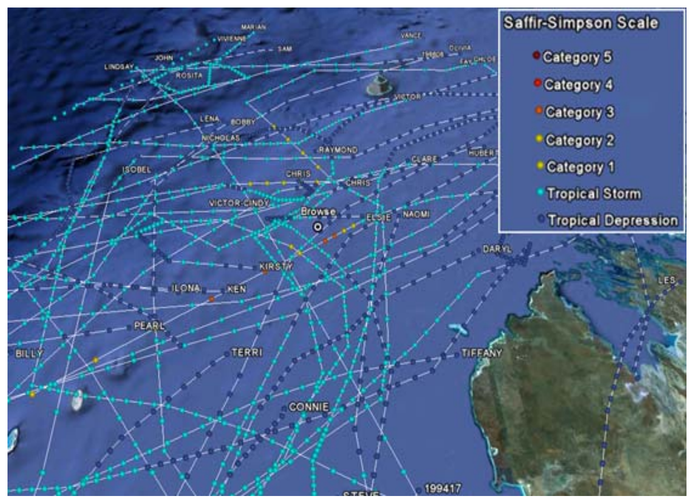

Figure 6. Hurricane Track and Severity in the Browse Region.

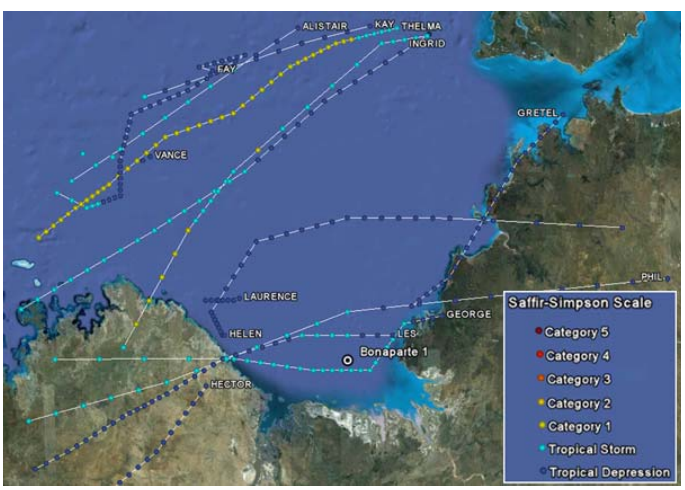

Figure 4. Hurricane Track and Severity in the Bonaparte 1 Region.

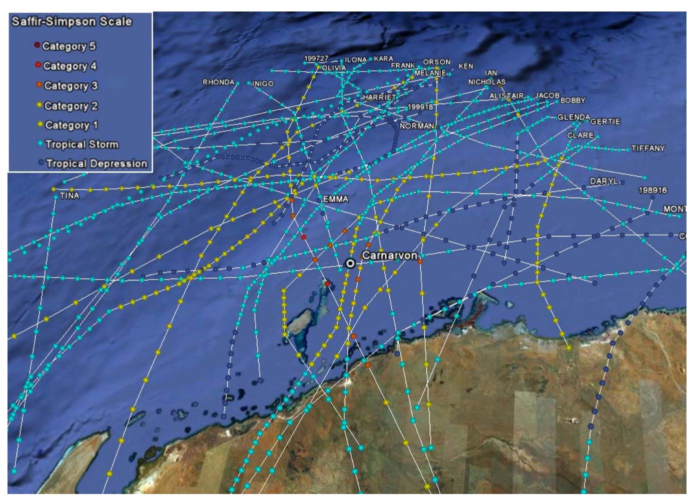

Figure 7. Hurricane Track and Severity in the Carnarvon Region.

The offshore Australian region has utilized a synthetic typhoon database since its well recorded data is not as long as the Gulf of Mexico. This synthetic database should also be integrated into a risk assessment process to extract the patterns and trends in each region of interest to better understand the metocean impact.

B. Soils and Anchoring

Soil and mooring line catenary conditions and how they affect anchoring must also be well understood. Most importantly are the relative reliability differences or similarities with anchor performance between the two regions. Since a majority of the experience gained in the Gulf is going to be applied to the Western Pacific, a review of fundamental performance must be carried out. Fig. 8 illustrates the number of locations in 2009 that utilized each type of moored MODU anchor foundation.

Drag embedment anchors are the most utilized anchor foundation for moored MODUs around the world. There are several key factors that should be considered when trying to evaluate their performance in a risk assessment.

First, the proof (or test) load of the anchor will play a big role on whether or not the anchor will predictably embed into the seafloor. If through analysis, it is determined that the proof load does not fully embed the fluke of the anchor, such an installation should have a higher risk associated with potential anchor failure. Even if site-specific soil conditions are not known, an upper and lower bound approach could be utilized and evaluated for this condition.

Second, the impact of the anchor uplift angle must be considered to indicate at which point in loading the trajectory of the anchor might lead to failure. This is accomplished by carrying out an anchor trajectory analysis for the specific mooring line configurations being utilized and again with either site-specific soils or appropriate upper and lower bound assumptions. Utilization of generic anchor holding capacity values should lead to a higher risk factor in comparison to a site-specific, configuration specific anchor assessment.

The next most common anchors utilized for moored MODUs are drag installed Vertically Loaded Anchors (VLAs). VLAs typically require a two step installation process by which the anchor is drug in to a certain depth then a shear pin is broken, orientating the anchor fluke such that it can better resist vertical load. This type of anchor foundation actually had the highest failure rate in the three major hurricanes in the Gulf of Mexico, thus it’s generally thought that a detailed anchor analysis is even more critical for these anchors.

Since most mooring applications with VLAs have high levels of anchor uplift angles, the effect of the relationship between load and uplift on the anchor fluke trajectory is critical. The additional effects of the soil resistance on the mooring line component in the seabed also play a critical role in determining the anchor fluke’s actual trajectory. The capacity will be limited by the depth at which the trajectory becomes flat. In some cases, this may also be associated with excessive horizontal displacement. For a given location near subsea pipelines, this displacement may perhaps be too great to offer any reduction in risk factors.

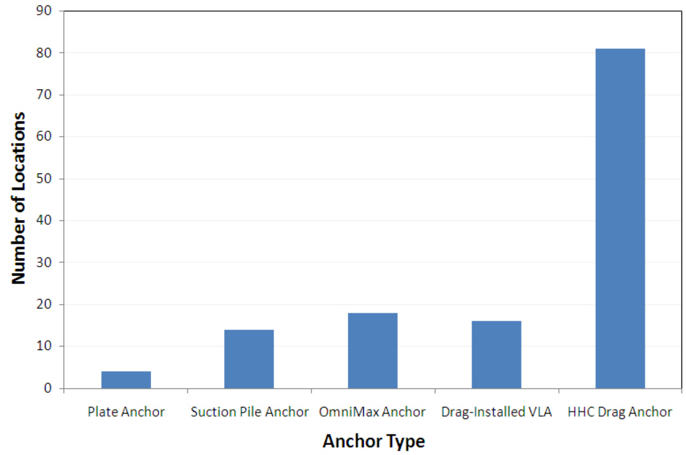

Figure 8. 2009 Anchor Type Utilization Summary.

The third most commonly utilized anchor used in these risk assessments is the OMNI-Max. This anchor is gravity installed and offers near equal capacity in all 360-degree around the foundation. This anchor also penetrates deeper into the soil like a drag anchor once loaded to strong hurricane or typhoon loads. Pull-out risk is the lowest with this foundation and thus it can be utilized as a mitigating technology that almost completely eliminates risk to subsea assets, leaving only surface collision.

Analysis of OMNI-Max anchors must be completed as with any anchor that is required to move when under load. So trajectory analysis should be completed for each location in order to be able to rely on its performance as mitigation for subsea risk events.

Suction pile anchors are still utilized and because they are designed for MODUs with typically larger factors of safety, the only event occurring from a failure is loss of the connection padeye and dragging it along with the mooring components. Thus the likelihood of large pipelines is minimal when using suction pile anchors. Umbilical and smaller subsea flowlines can be more prone to damage if a suction pile padeye were failed structurally due to large out-of-plane bending and being drug by a failed MODU.

C. Predicting Failure Probability

Both the Western Pacific Ocean and the Gulf of Mexico are prone to tropical cyclones. Whether its hurricanes in the Gulf or Typhoons in the Western Pacific; these huge storms drive moored MODU failure probability. The calibration carried out for the failure probability in the Gulf should translate very closely to that of moored MODUs in the Western Pacific. Thus the same factors based on the intact mooring system line tension factor of safety of 1.2 should be a good indicator of controlling system failure probability.

The worst case direction from the mooring analysis should also be the main probability of failure indication. The typhoons in the area over the last 24-years indicate that directionality on controlling winds is more unpredictable than the Gulf. The Carnarvon region storms are a good indication of this. Fig. 9 illustrates the wind speed directionality assessment for a location using the typhoon modeler.

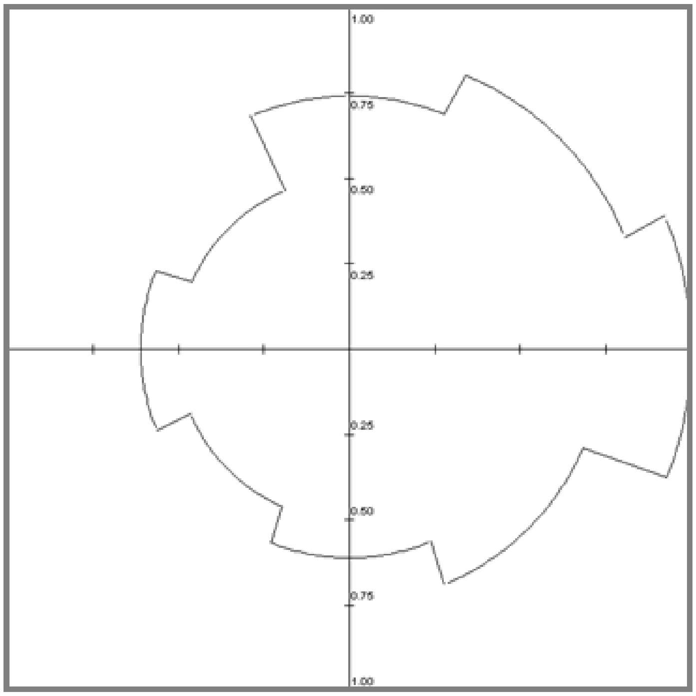

Figure 9. Typhoon Directionality in the Carnarvon Region (Cat 1).

As shown, the winds appear in all directions. The more intense Category 3 and 4 winds however start to show some directionality favoring the north and western directions; however the number of well recorded typhoons is relatively low.

IV. Application to Dynamically Positioned and Jackup MODUs

Both Dynamically Positioned (DP) and Jackup MODUs could also be evaluated with a version of this risk assessment method. One of the fundamental keys to all MODU risk assessment is the interpretation and use of the metocean data for each site.

For a DP MODU, the metocean data can be used to determine the probability of getting caught by a tropical cyclone given a calculated transit time at any given point in the drilling operations. The metocean data can also be looked at from the other way by plotting the probability of getting caught against transit time and so the operator can better manage what types of (long transit time) operations are best done outside of the riskiest time of the cyclonic season.

For a Jackup MODU, the metocean data can be used in both geotechnical failure and wave-in-deck failure. The wind speeds can lead to the probability of blowing the Jackup over given a foundation capacity. And the wave heights can lead to the probability of deck slamming leading to station keeping loss. Higher deck elevations will create higher probability of blow over and lower probability of wave slamming, thus they work against each other. This means that if the calculations are done correctly, an optimum airgap can be selected that will maximize the survivability of the Jackup and offer the lowest risk option for a given preload condition. Mitigation measures to reduce risk would typically be additional preload.

V. Conclusion

The Western Pacific Oceans offers many of the same offshore oil and gas rewards as the US Gulf of Mexico, but also many of the same design and risk challenges. Managing the risk of moored MODU failure can be accomplished by at least in part the use of the risk assessment method described within this paper. By automatically sorting through thousands of independent risk events, the operator can make more informed decisions on drilling activity and better spend time and resources mitigating the main controlling risk events. This method also allows regulators to use a uniform approach to evaluating individual moored MODU risk assessments and help manage overall fleet risk to existing infrastructure.

Acknowledgment

This risk assessment process would not have been as successful without the significant help and encouragement of Dr. Malcolm Sharples, Mrs. Jane Powers, Mr. Jason Mathews and Mr. Lance Labiche.

References

[1] Evan H Zimmerman, Malcom Sharples and Daniel J. Alonso, "Delmar MODU Mooring Risk Assessment JIP Report," Houston, December 2007.
[2] ABS Consulting, "MODU Mooring Strength and Reliability Summary Report," Houston, July 2008.
[3] E.H. Zimmerman, M.W. Smith and J.T. Shelton, "Efficient Gravity Installed Anchor for Deepwater Mooring," Houston, May 2009.