

MODU Performance in Hurricane Ivan

Hurricane Ivan tracked through a high-density corridor of mobile offshore drilling units (MODUs) in the U.S. Gulf of Mexico (GOM), resulting in five semi-submersibles losing station and collapse of one jackup. In the aftermath of this hurricane, the industry is reflecting on lessons learned and re-examining industry standards. There was no loss of life and no major pollution from MODUs in Hurricane Ivan. A study commissioned by the U.S. Minerals Management Service (MMS) has chronicled the incidents of Hurricane Ivan to provide information that may lead to more-robust criteria for MODU safety.

Introduction

A study was commissioned by the MMS to gather information and examine MODU loss of station keeping during Hurricane Ivan. There were approximately 112 jackups and 32 semisubmersibles in the GOM at the time of Hurricane Ivan. Only three jackups were affected, and only one of those was a total loss. Five semisubmersibles were affected. Four left their general location and became adrift, and one moved approximately 3,000 ft. Most of the information came directly from drilling contractors, some came from oil companies, and some came from MMS files. Because the study was not com-

This article, written by Assistant Technology Editor Karen Bybee, contains highlights of paper OTC 18322, "MODU Performance in Hurricane Ivan," by B.P.M. Sharples, SPE, Offshore Risk & Technology Consulting Inc., and S. Buffington, U.S. Minerals Management Service, prepared for the 2006 Offshore Technology Conference, Houston, 1-4 May.

Copyright 2006 Offshore Technology Conference. Reproduced by permission.

plete at the time the full-length paper was written, the information is preliminary and subject to correction and change.

Overview

In September 2004, Hurricane Ivan, a Category 4 storm with waves exceeding the 100-year design criteria for offshore facilities, moved through the GOM. Of the more than 4,000 offshore oil and gas facilities and 33,000 miles of pipelines in federal waters, approximately 150 facilities and 10,000 miles of pipelines were in the direct path of Ivan. Damaged facilities included MODUs, offshore platforms, producing wells, topside systems, and pipeline systems that transport oil and gas ashore. MMS received industry reports indicating that seven platforms were destroyed, six platforms and five drilling rigs had major damage, and a substantial amount of oil and gas production remained shut-in because of pipeline damage.

Semisubmersible MODUs

Ocean Star and Ocean American. Diamond Offshore Drilling reported that drill platform *Ocean Star* drifted from its moored location. A visual inspection by fixed-wing aircraft confirmed that *Ocean Star* was afloat with no apparent damage. A visual inspection by aircraft of four other Diamond Offshore rigs operating in the path of Ivan also indicated no apparent damage or pollution. The *Ocean Star* was approximately 1.5 miles east of the storm track. Most of the wires were said to have broken below the rig fairlead near the highest loading point on the system. Hindcast weather data clearly show that conditions exceeded the American Petroleum Inst. (API) 10-year design criteria.



Fig. 1—Ensko 64 after Hurricane Ivan.

The wind speed and thus the forces on the *Ocean American* moorings were higher than those of any other semi-submersible in the storm path and exceeded those that would have been appropriate even for a 100-year design condition. The *Ocean Star* and *Ocean American* were moved to a shallow-water location where anchor chain and wire lost during the storm were to be replaced. Estimated downtime for each rig was approximately 10 to 21 days.

Noble Jim Thompson. The mooring system of the Noble Drilling's *Noble Jim Thompson* was designed according to the accepted API 10-year criteria with a nine-point preset, semitaught steel mooring. The rig experienced API 100-year storm conditions according to information derived from hindcast ocean conditions. With the increased current value combined with a wind speed 40% more than design values, the loads would be expected to exceed the breaking value of the lines.

The *Noble Jim Thompson* apparently moved off to the west and then turned east to arrive approximately 40 miles to the southeast of its original location. The rig was damaged when the crane

The full-length paper is available for purchase at the OTC Library: www.otcnet.org. The paper has not been peer reviewed.

came free of the cradled position and swung inboard. A set of HT 65 tongs were found to have broken free from a securing rope and had been swinging freely for an undetermined length of time during the storm. The tongs were swinging at a height that allowed them to contact the racking-system control chair, causing extensive electrical and structural damage. The fast rescue boat was severely damaged when it was freed from its pinned position and contacted the rig structure as it moved with rig motion. The test stump inspection platform beneath the blowout-preventer (BOP) storage area was damaged severely. All satellite dishes and the satellite tracking dome for the telephone system were severely damaged. Other than the moorings and topside damage, the rig survived well and was back at work in a short period of time.

Deepwater Nautilus. Transocean's *Deepwater Nautilus*, originally designed as a deepwater semisubmersible, was moored on location with suction piles and pre-laid moorings on an eight-point symmetrical mooring pattern. The mooring system included 15,000 ft of high-strength 3³/₄-in. wire with a 1,565-kip breaking load. The *Deepwater Nautilus* was moored approximately 17 miles to the east of the storm. While it is difficult to determine the time of the first break or the weather conditions, analysis has predicted that the *Deepwater Nautilus* did not part her moorings until a storm value equivalent to an 85-year return period was upon it. Later the location was subject to higher wind speeds and wave heights. Hindcast ocean conditions indicate that at some point the metocean conditions would have reached an equivalent of a 100-year period at this location. The structure was found drifting approximately 70 miles from the well it had been drilling, upright and apparently undamaged.

Noble Lorris Bouzigard. Noble Drilling's *Noble Lorris Bouzigard*, originally a Pentagon 85 rig, was upgraded for deepwater service. While it was approximately 26 miles west of the storm, it experienced winds, waves, and currents equal to almost a 100-year event rather than the 10-year event for which the moorings were designed. While the forces on the unit were substantial, it is not obvious with-

out significant calculations and further investigation to determine whether it would be expected to fail. With a wind force equal to 1.7 times that for which it was designed, failure would be expected. The rig moved approximately 3,000 ft. Because the anchors were designed to be drag anchors, it is not surprising that the unit survived without breaking because drag anchors allow the loads to redistribute. The wave crest did some damage to the BOP garage, which needed extensive repairs. Other than this, the unit weathered the storm well and was back at work within 10 days.

Noble Max Smith. Noble Drilling's *Noble Max Smith* was approximately 47 miles to the west of the storm. The conditions there were somewhat greater than the 10-year values used in mooring design. The *Noble Max Smith* had no apparent problem in maintaining location, nor was there any damage. Of interest is that it confirmed that for this storm, the required distance from the track for having issues was approximately 50 miles.

Deepwater Horizon. Transocean's *Deepwater Horizon* is a fifth-generation deepwater MODU with propulsion and can transit without tug assistance. From 9 to 11 September, the *Deepwater Horizon* was at Green Canyon Block 743 waiting on current to safely detach the riser. The rig experienced currents greater than 3.5 knots resulting from migration of the Eddy Ulysses western-front current across the location. Disconnect was performed with a 3.3-knot surface-current reading.

The planned move to the south/southwest to find lower currents was hampered by the prevailing opposing 2.6-knot current. Drifting with the current to the northeast was not an alternative because of the proximity of the escarpment 2,300-ft elevation within 2 miles. It also was not prudent to try to go to the southeast or east because of high currents and the path of the approaching storm. Because of the high currents and ability to move only at 0.3 knots, the rig remained in high currents. The movement was not hampered by the capability of the vessel but by the need to prevent severe oscillation of the riser and high bending and shear loads in the top of the riser. Forty-four personnel remained safely on board during the storm as they attempted to maneuver

with the riser hanging. After the passage of Hurricane Ivan, the rig moved to the southeast to find lower currents of 1.3 knots.

Jackup MODUs

Jackups have been used in the GOM since the mid-1950s, and there have been few failures in that time. Very few jackups have been lost as a result of hurricanes, considering the number that work in the GOM. While a 10-year hurricane event generally has been used as a design condition for jackups, recently the Soc. of Naval Architects and Marine Engineers GOM Annex Committee has been developing more rational criteria to ensure that jackup designs structurally can withstand events to ensure personnel safety during a conservative evacuation period after a hurricane is declared and on the basis of a 50-year "sudden-hurricane" event.

Ensco 64. The Ensco Intl. Inc. *Ensco 64* was a Letourneau 53 Class slot jackup built in 1973. It had been upgraded to increase the leg length to 477 ft, reinforce the legs, and increase the preload capacity to increase water-depth capability. It was at its deepest water depth at this location. *Ensco 64* was stationed 6 miles to the west of the central path of the eye. The air gap, 46 ft, would have allowed the jackup to weather most 100-year storms and was close to the 48.5 ft recommended by API RP 2A. On the basis of calculations made after the specific wind and wave data for Ivan were available, it is likely that the hull was inundated with waves. To have survived, the air gap would have needed to be closer to 58 ft.

The wind, waves, and current exceeded the design by a large margin. Ivan imposed forces on the rig almost double the design wave height. The legs sheared off below the hull. All three legs failed. One leg had a length of 100 ft, another a 65-ft length, while the third leg was completely gone. **Fig. 1** shows the *Ensco 64* after Ivan.

The 200. Todco's *The 200* is a Bethlehem 200 Class cantilever rig, built in 1979. There were a number of this type of rig built by Bethlehem, many of which still work in the shallower waters of the GOM. Operating capability of *The 200* is 200 ft, and with a water depth of 72 ft, its capability exceeded that which was indicated in the operating manual.

The 200 had no failures and no issues according to a detailed structural inspection. The 6- to 8-ft scour at the forward end of the mat and approximately 4-ft scour at the stern end, resulting from the passage of the storm, caused the rig to be relocated for continuation of its work.

Ocean Warwick. Diamond Offshore Drilling's *Ocean Warwick* was a Levingston 111 Class jackup with 418 ft of leg. This was one of the "standard" designs in the early 1970s. The *Ocean Warwick* was in 185 ft of water, well within the water-depth capability of the rig, and was approximately 21 miles west of the storm track.

Comparison of the actual to design conditions shows that the design condition would have been exceeded even on the basis of a 1-knot current. With a 3.8-knot current, the capability would have been further decreased with some minor damage expected.

The air gap would have to be 52 ft to have survived, so on the basis of customary practice of an approximately 50-ft air gap, there would be no expect-

ed inundation of the hull by waves. The loads were such that some damage to the legs might be expected. There were multimode cracks in all three legs from 248 to 296 ft. The starboard preload tank bulkhead buckled. The wellhead impaled on the hull. All three jack houses were damaged.

Ocean Columbia and Ocean Drake. Diamond Offshore Drilling's *Ocean Columbia* and *Ocean Drake* were approximately 40 and 50 miles, respectively, from hurricane-force winds. This was outside of the MMS path of concern for fixed platforms. Comparison of metocean conditions with design conditions indicates that no damage would be expected, and none was reported. It was stated in one report that wave action from the storm destabilized the *Ocean Drake* drilling site. *Ocean Columbia* proceeded to its next drilling location.

Interim Conclusions

Floating MODUs. It is not desirable for semisubmersibles to become adrift and potentially affect other structures.

The joint-industry project may lead to new criteria that may be risk-based and may lead to a reduced risk to the critical infrastructure from drifting MODUs during hurricanes. There is a need to instrument some semisubmersibles to benchmark mooring-analysis assumptions and methodology. MMS is evaluating how to encourage operators to add instrumentation to gather this information.

Part of the standards to be developed will consider an enhanced-quality system as applied to pre-laid and rig moorings. A number of wires failed in areas where it might not be expected normally.

Jackup MODUs. Jackup performance in Hurricane Ivan can be said to be "as expected." Comparing the hindcast data to the API 10-year criteria (a general estimate of criteria close to the 50-year "sudden-hurricane" values), it appears that the jackups' performance, in general, exceeded their design criteria. **JPT**