Noble's newbuild jackups incorporate system to monitor, combat rack phase differential

By Harvey Duhaney, Harold Keys,
Noble Drilling Services

WITH THE MOVEMENT into ever deeper waters, environmental drilling and storm variable load demands have risen. Jackup rig designs have had to continually evolve to address these increasing demands as well. **Noble Drilling**'s latest generation of premium jackup rigs includes 3 JU-2000E rigs now under construction. These vessels incorporate several advanced features and capabilities.

One of the problems plaguing jackup drilling units, especially those with the newest leg designs, is uneven phasing of leg cord racks. Jackup leg designs have been streamlined to present smaller cross-sectional areas to environmental forces including waves, wind, surface and subsurface currents. Uneven chord phasing, termed Rack Phase Differential (RPD), is caused by uneven bearing loads and can lead to damaged leg braces.

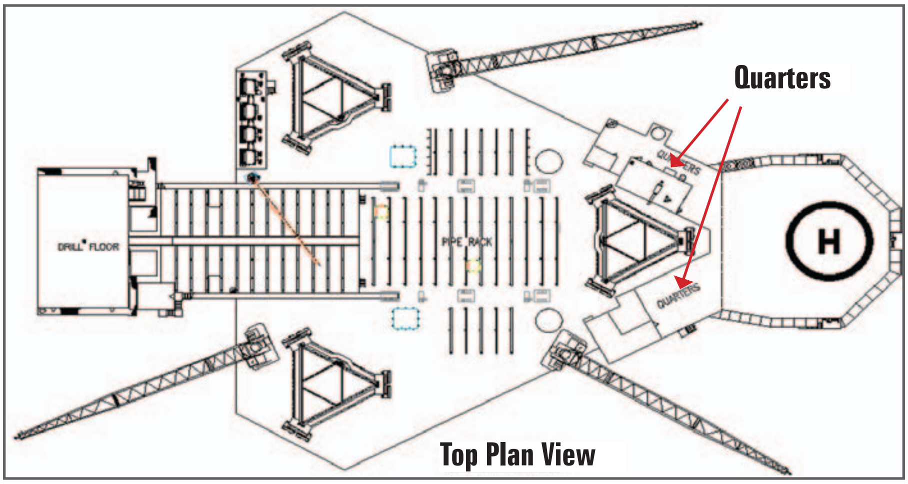
NEWBUILD JACKUPS

Noble Drilling has contracted to build 3 premium jackup rigs (JU-2000E designed by **Friede & Goldman**) that can operate in water up to 400 ft (122 m) deep. These vessels incorporate a variety of advanced features and capabilities.

The first of these new jackups (Figure 1) is the Noble Roger Lewis to be delivered from Dalian, China, in fall 2007. This rig is contracted for operations with **Shell** in the Arabian Gulf. The second rig, the Noble Hans Deul, is scheduled to be delivered in the second quarter of 2008 for Shell in the North Sea. Noble's third new jackup, the Noble Scott Marks, is scheduled to be delivered in the second quarter of 2009 for **Ventura** in the North Sea.

LEG ENHANCEMENT

The chords in each leg are composed of a split tubular outer wall welded to the 7-in. rack. Bracing is designed in a reverse "K" pattern, which reduces drag forces due to environmental loading by 7% compared with standard "X" bracing. This improvement allows greater environmental and variable deck loads. The "K" bracing pattern reduces leg weight while maintaining a high stiffness-to-weight ratio.



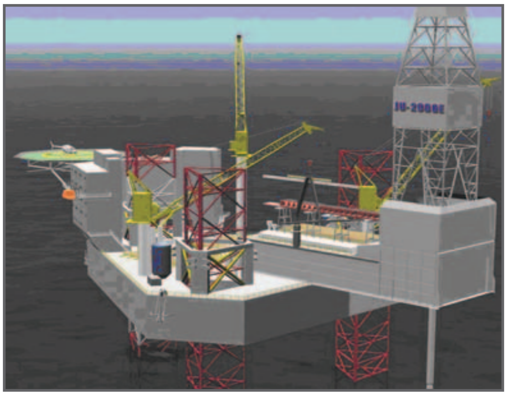


Figure 1 (left): One of Noble's 3 newbuild jackups, the Noble Roger Lewis, is already contracted for operations with Shell in the Arabian Gulf. Figure 2 (above): A top plan view of the JU-2000E shows that living quarters are located around the bow leg to optimize deck space. This arrangement also puts the quarters' dead weight at forward end, offsetting higher drilling loads of the rig.

VESSEL DIMENSIONS

JU-2000E vessels consists of a triangular hull, which is 231 ft (70.4 m) long, 250 ft (76.2 m) wide and 31 ft (9.45 m) deep. The cantilever is capable of skidding out to a maximum outreach of 75 ft (23 m), and the substructure can skid to port and starboard by 15 ft (4.6 m).

The maximum drilling variable deck load is 14,400 kip (6534 t) with a maximum survival deck load of 6600 kip (2995 t). The significantly higher drilling variable load provides for greater operational flexibility.

DECK SPACE

One of the most important considerations in jackup design is deck space. The JU-2000E is larger than any jackup currently under construction and correspondingly has more deck space. Usable deck space was optimized by providing the living quarters around the bow leg (figure 2). This arrangement also assists in overall global loading of the rig in the elevated condition. The dead weight of the living quarters at forward end offset higher drilling loads aft of the rig.

To further increase deck space, all mud processing, cementing, mud logging, and BOP controls are contained within the main body of the cantilever. Storing these equipments within the cantilever eliminates dead space and reduces piping runs from the drill floor.

MODULAR HULL DESIGN

To make hull construction simpler and less expensive, the JU-2000E is based on a modular hull design (figure 3). It is comprised of 4 basic shapes (total of eight sections) that are used throughout the rig. A significant benefit of a modular approach is that multiple shipyards can construct different parts of the hull. This can accelerate delivery compared with a conventional unit. Also, the hull form can be customized to address specific needs with minimal rework. Each part of the 4 basic modules is very similar. This means that fabrication and assembly work is repetitive, and the potential for mistakes is reduced.

BOP & DIVERTER

The demand for premium rigs drilling in deeper water and deeper depths necessitates an increase in BOP system pressure. 15,000 psi is becoming the standard for the industry. The BOP stack in JU2000E is an 18 ¾-in. (47.6 cm), 15,000 psi (1,055 kg/cm^2) system. The diverter is 47 ½-in. (125.7 cm).

BOP HANDLING SYSTEM

Deeper wells require a heavier BOP system to handle increased pressure. As a result, the BOP handling system requires an overall upgrade. One of the improvements in the JU2000E is the ability of the handling system to travel in both the directions – longitudinal and transverse. These 2-way movements facilitate greater flexibility with handling/testing/storing BOP. Because the BOP can be stored forward of the well-center, it helps in reducing the cantilever loads and increasing the drilling capacity.

The BOP handling system consists of a rail mounted 113 Mtons hydraulic lifting crane. In addition, the unit is equipped with an electrically operated 27 Mtons bridge crane for service and maintenance of the BOP stacks.

CONDUCTOR TENSIONING SYSTEM

The vessel is equipped with primary and secondary conductor tensioning systems. The primary system is located on a conductor tension unit (CTU) hung from and below the cantilever. This system consists of 4 pairs of hydraulic cylinders driving a lift-ring assembly, which reacts against a load collar attached to the conductor pipe to apply vertical tension of up to 272 Mtons at any position of the cantilever and substructure and up to 136 Mtons secondary tension to the BOP stack. The secondary tensioning system supports the weight of the BOP stack, thus reducing stress loading on the riser.

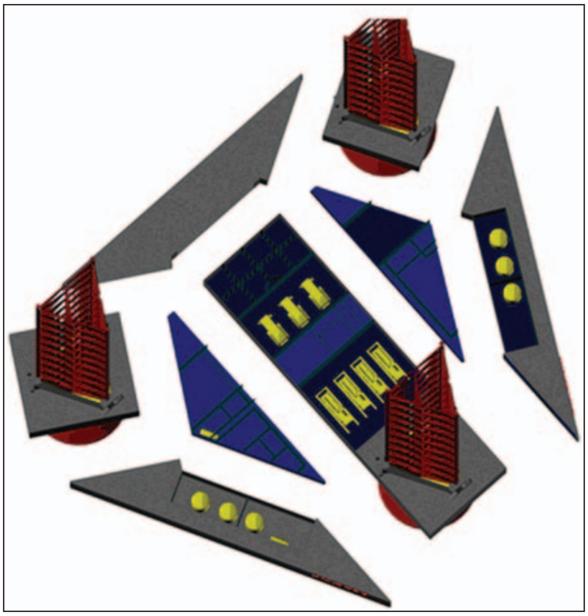


Figure 3: The JU-2000E is based on a modular hull design comprising of 4 basic shapes and a total of 8 sections. A significant benefit of a modular approach is that multiple shipyards can construct different parts of the hull. This can accelerate delivery compared with a conventional unit. Also, the hull form can be customized to address specific needs with minimal rework.

PIPE HANDLING

The unit is equipped with a remotely operated automated pipe handling system to transfer pipe from the cantilever pipe deck to the rig floor. The rig is also equipped with a knuckle boom crane on the port cantilever. It helps in handling the drill pipe without interfering with the operation of the 3 primary rig cranes.

RPD

One of the current issues affecting jack-up drilling units, especially those with the newer leg designs, is the effect of leg cord Rack Phasing, which causes damage to individual leg members, commonly referred to as Rack Phase Differential (RPD). This effect arises under 3 general situations:

- Jacking up on uneven bottoms causes each leg cord on 1 or more legs to experience differing bearing loads (figure 4a).

During elevated operations, scour conditions under the spud can result in unbalanced leg cord loading (figure 4b).

- Extracting the chock system and loading the rig back onto the jacking pinions can cause RPD as well in the event individual system torque cannot be determined or set properly.

RPD occurs most often on locations with a disturbed or uneven seabed, resulting in eccentric bearing support of the leg's spud can and causing the can to move horizontally. RPD is most likely in situations with (1) pre-existing spud can holes, (2) sloping seabed, (3) uneven seabed, (4) uneven seabed due to scour, (5) leg splay, or (6) rapid penetration.

All jackup rig designs experience RPD, but only certain classes (primarily units with low cross-sectional leg members) experience RPD to the point of leg damage. In the current jackup fleet, rig class-

Table 1: Environmental capacities

DESCRIPTION	Environmental Condition 1	Environmental Condition 2	Environmental Condition 3
Water depth	328 ft/100 m	350 ft/107 m	400 ft/122 m
Maximum wave height	72 ft/22m	57 ft/17m	60 ft/18m
Wave period	15.5 sec	15.5 sec	14.1 sec
Wind speed (1 min. mean)	87 knots/45 m/s	100 knots/52 m/s	100 knots/52 m/s
Surface current	1 knot/0.5 m/s	2 knots/1 m/s	1.5 knots/0.8 m/s
Air gap	65 ft/20 m	50 ft/15 m	40 ft/12 m
Penetration	10 ft/3 m	10 ft/3 m	10 ft/3 m

es such as the F&G L-780 can sustain up to 3 in. (76 mm) of RPD before leg member failure occurs. The KFEL Mod-VB can sustain up to 5 in. of RPD (127 mm). The new JU-2000E described is designed to sustain up to 8 in. of RPD (203 mm) before leg member failure.

MANAGING RPD

Location evaluation prior to rig arrival on-site is the most critical factor for reducing RPD effects. A complete location evaluation can be performed by doing bottom surveys, geo hazard surveys and soil analysis.

The second most critical stage for monitoring RPD occurs when the rig is set up on location. Early detection of RPD helps prevent the operation from continuing into damage-producing stresses.

Soil properties have a critical impact on the process. In typical locations with a hard seabed and minimal penetration, there is very limited potential for manipulating the seabed while elevated. When the seabed is hard, RPD is typically eliminated by reseating the spud can. If RPD is monitored before full bearing pressure is achieved, there can be limited ability to manipulate the seabed (referred to as "stomping" or "pre-forming").

Operators have found that manipulation of the seabed in later stages of the setup process is more likely to successfully reduce RPD when softer, more pliable soils are present. For all soil types, the best opportunities for managing RPD are during the initial stages of setting up on location.

Basic techniques employed to counter RPD after it is observed includes reseating, changing chord loads by releasing brakes & independent chord jacking, intentionally imposing reverse RPD, and tilting the rig.

DISPLAY, ALARM SYSTEM

The JU-2000E jacking system has the ability to monitor gear unit torque from the Jacking Console and set the torque individually for each gear unit. In addition, the jacking system includes a Rack Phase Display and Alarm System to monitor differential as it occurs. This enables the jacking operator to stop jacking operations to evaluate any effects of RPD and to institute appropriate mitigation procedures.

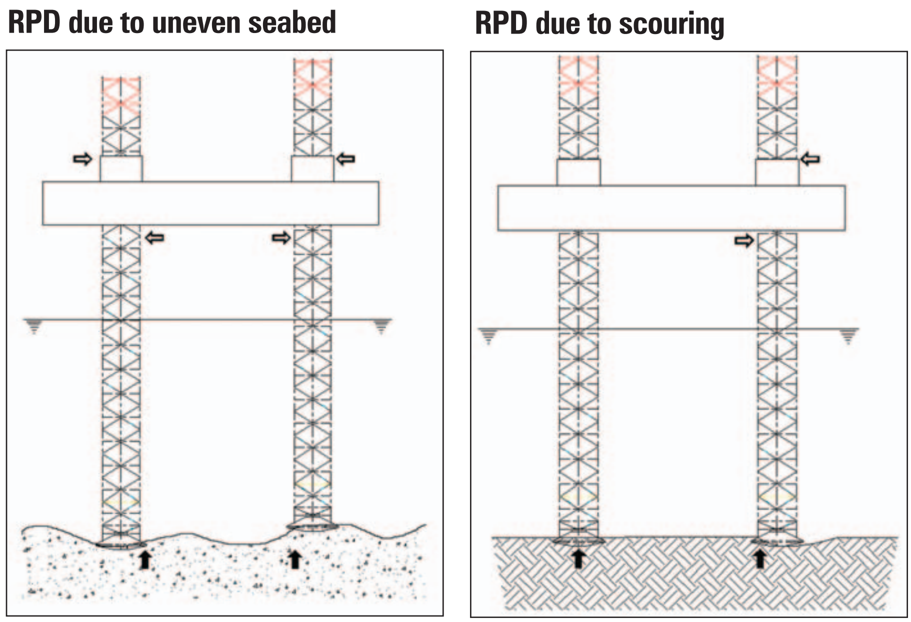
RPD DISPLAY

The RPD display shows relative differences in displacement of the 3 chords for each leg. Displacement of each chord is measured by a Leg Height Detector fitted at each chord on top of the jacking structure. The detector consists of an idle pinion that meshes with the rack and rotates only during the vertical displacement of the chord (figure 5). This pinion drives 2 pulse counters that deliver signals to the MCC, which processes these signals and display the RPD values on the central jacking console for each leg.

The RPD display does not automatically halt jacking operations. However, it does deliver an audible warning if RPD exceeds 3 in. (76 mm). Values of chord relative displacement are displayed for the jacking operator, who then decides when and which correction is necessary.

The jacking system includes a central jacking console and 9 local consoles (1 for each chord). The local consoles interface with the Rack Chock System engagement. Length of the leg deployed below the hull is displayed on the same screen as the Pinion Load Monitoring System screen, located on the Jacking Central Console.

Once RPD has been determined to exist, procedures in the Marine Operating Manual (MOM) address the actions to be taken to mitigate the effects.



Figures 4a (left) and 4b: Rack Phase Differential (RPD) can arise when jacking up on uneven bottoms causes each leg cord on one or more legs to experience differing bearing loads, as illustrated in the graphic above left. RPD can also occur during elevated operations when scour conditions under the spud results in unbalanced leg cord loading, as shown in the graphic above right.

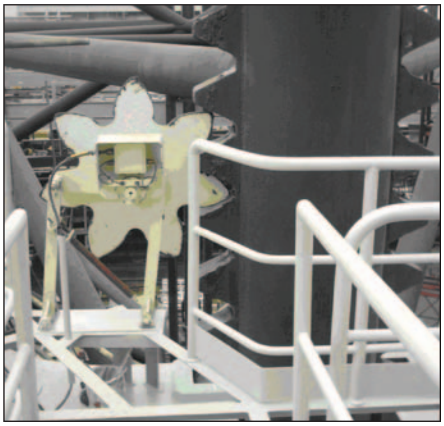


Figure 5: The Leg Height Detector measures displacement of the 3 chords for each leg and is fitted at each chord on top of the jacking structure.

CONCLUSIONS

The JU-2000E is one of the most versatile jack up units yet designed to operate in hostile environments and yet maintain more than adequate drilling VDL and operational capabilities for today's demanding requirements.

To combat rack phase differential (RPD), these new rigs incorporate an advanced jacking system that has the ability to monitor gear unit torque from the jacking console and set the torque individually for each gear unit. A special display and alarm system allows the operator to evaluate RPD and implement mitigation procedures before serious problems occur.