Kuwait Oil Co designs, builds semi-automated 3,000-hp rig to tap deep HPHT resources

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Kuwait Oil Company's HAH Rig 124 was designed to provide a superior deep-drilling rig at a competitive rate. KOC's focus was well cost rather than low rates.

DRILLING OF DEEP HPHT wells in Kuwait requires both local and international drilling contractors to adhere strictly to overall required capacities of equipment for safely and efficiently drilling Jurassic and deeper exploratory prospects from depths of 15,000 ft to more than 22,000 ft TVD. This requires use of 3,000-hp rigs due to heavy casing hookloads for the 24-in. and 18 5/8-in. casings, high mud weights at relatively deep depths in 16-in. and 12 ¼-in. hole sections, and fairly high torques throughout the well. Likewise, mud volumes in these wells require adequate capacities and processing capabilities for the larger hole sections, especially when dealing with 19.5-ppg mud systems with a solids content of around 45% in the 12 ¼-in. hole section at 14,000 ft.

Typical casing loads of 1.3 MM lbs occur during lowering of the 18 5/8-in. intermediate casing, maximum flow rates of 1,200 to 900 gpm (depending on mud weight) with surface pumping pressures greater than 4,500 psi are seen in the drilling of the 16-in. hole section utilizing PDC bits in conjunction with performance type mud motors, and on bottom drilling torques of over 20,000 ft-lbs occur in the drilling of the 28-in. hole section for these wells.

In addition to the basic load requirements in the present Jurassic and Khuff well designs, possible future well design for exploratory HPHT gas wells over 25,000 ft deep dictates that use of even more pumping horsepower as well as semi-automated control system to allow the smoothest transfer of surface parameters to the bit is recommended. Offset data from the Khuff well tended to justify the requirement for more power and capacity if the target depth of 25,000 ft is to be met, and this was a key driver for designing a state-of-the-art rig.

Even more importantly, upgrading or building new 3,000-hp rigs to reduce overall nonproductive time (NPT) and related unscheduled events was an achievable goal that KOC began pursuing in 2001. A prime example of NPT operations improvement can be seen in the reduced instances of stuck pipe by utilization of the top drive to reduce the critical time delay from when the pipe initially sticks to when torque can be applied to free it. Another example is picking up drill pipe offline, using either the iron roughneck or rotating mouse hole, as well as the decreased connection time overall while drilling with stands instead of single joints of drill pipe.

Above all, safety was given the utmost consideration when looking at an upgrade or building of these 3,000-hp rigs. An example of equipment used to reduce risk of repetitive motion injuries can be seen in the iron roughneck and automatic slips used in tripping operations. Use of these devices, from a safety perspective, to reduce the risk of predominant repetitive motion type injuries to the lower back and fingers has been taken into account as a safe working rig environment and has proven to be a more productive rig environment.

Partly as a result of the successes from the earlier rig upgrades, KOC began pursuing a newbuild 3,000-hp rig in mid-2002. **Kuwait Drilling Company** was awarded the contract, and newbuild KDC Rig 15 was built during 2003 and commissioned in April 2004 as the first Kuwait contractor-owned advanced 3,000-hp drilling rig. This rig has proven to be an asset to deep-drilling strategy and continues to deliver ongoing improvements in performance.

With the anticipation of even deeper exploratory prospects to 25,000 ft in the not-too-distant KOC future, and with the successes of rigs KDC-15 and KSF 24, a deep-drilling contract strategy was developed and presented to management in 2003 to build an even more sophisticated semi-automated 3,000-hp drilling rig for Kuwait.

CONTRACTING STRATEGY

1. Focus on contractor health, safety and environment performance.

2. Continuous Quality Improvement.

3. Access to new technology through links with international drilling contractors.

4. Pro-active and cooperative development of local contractor HPHT drilling capabilities.

5. Focus on high-performance rather than low rates to reduce well costs.

6. 6-year forward planning.

7. Selection and award based on performance and capability.

Item 4 was viewed as key to Kuwait's future success in building and maintaining a localized 3,000-hp deep-drilling fleet capable of competing in any world market, and this idea was combined with Item 3 to help secure approvals to pursue a single-source local contract for a newbuild state-of-the-art 3,000-hp rig, which offered the following technical advances:

- 3,000-hp drawworks
- Top drive system
- Semi-automatic control systems – drawworks and top drive
- 2200-hp mud pumps with 7,500-psi discharge pipework
- Rig floor iron roughneck
- Improved mud treating and handling systems (5 shakers)
- 5 ½-in. and 4-in. drill pipe
- 18 ¾-in., 15,000-psi BOP system
- Power slips

Contracting strategy also involved a detailed justification for the increased dayrate that a proposed rig of this nature would require to be commercially acceptable to both KOC and the contractor, **Hamad Al Hamad and Partners** (HAH). Therefore, each upgraded component would have to be shown to have a value added benefit over its respective cost increase to the dayrate. This cost comparison was performed using the presently contracted 3,000-hp rig KSF 24 as the reference base rig for dayrate.

One item that became evident in the initial estimated pricing of the components and estimated value added was that the primary contract term needed to run over a longer period than that of the normal rigs in order to allow the commercial risk to be spread out for payout.

PLANNING MEETING

In early 2004, meetings were held within the KOC Deep Drilling Team to formulate a strategy to work with the drilling contractor to obtain the best-value equipment for the proposed rig. The criteria included looking at such things as past lessons learned with respect to KDC Rig 15 and KSF Rig 24, adaptability of the equipment with respect to Kuwait's environment (hot weather and sand), interchangeability of equipment with other 3,000-hp rigs in Kuwait, and detailed technical specifications of the equipment.

The objective of the technical specification was to state what equipment was required to obtain a deep-drilling rig at a competitive dayrate that provided technical advantages over the deep-drilling rigs presently working for KOC.

This was accomplished by specifying items such as model numbers and technical ratings of the equipment so that minimal contract negotiations would be required to minimize any future problems due to equipment generalities. Original equipment manufacturer (OEM) was repeatedly consulted during the technical discussions in respect of the specification of equipment and parts for that equipment.

Meetings with several rig-building companies were held with both KOC and HAH in attendance to discuss technical details of equipment specifications. Likewise, meetings with mud solids processing companies, BOP companies and drill pipe manufacturers were held to compare specifications. Basically, the tender document from KOC to HAH reflected choices of technically superior equipment similar to a pre-qualification, from which competitive bidding was used to get to the final product.

TECHNICAL SPECIFICATION

3,000-hp drawworks – The requirement for enough drawworks to handle the 18 ⅝-in. casing loads in a smooth manner led to studying the use of AC versus DC power. Although AC power has become increasingly popular with drawworks and top drive systems, it was ultimately decided in 2003 to continue with DC power in the drawworks, mainly due to familiarity of the same with the present local electricians and mechanics.

Top drive system (TDS) – As with the previous upgraded or newbuild deep rigs, a TDS was deemed necessary with the semi-automated control system to provide more efficient and safer operations while drilling in stands with fewer connections, and to provide faster response to tight hole and differential sticking situations to lower NPT.

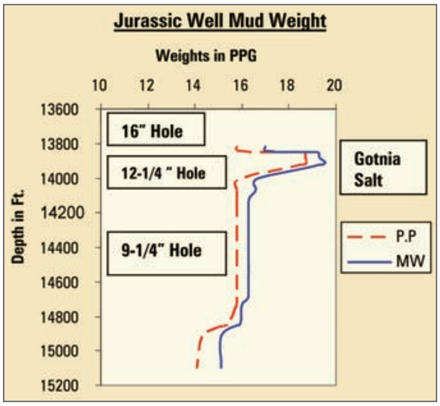
The TDS system was also looked at from the viewpoint of AC versus DC power requirement, and DC was chosen again with the previous experience of the local electricians and mechanics being a driving factor.

Automation – The semi-automated drilling control equipment was planned with several items in mind. Safety with respect to block incidents striking the crown or rig floor was a high priority on this list due to several incidents that occurred with respect to crown-o-matic use in late 2003 and early 2004. The proposed control equipment was designed to give a second "barrier" via position control stop to the traveling block as it approached the crown or rig floor.

Improvements concerning "on-bottom" rate of penetration (ROP) utilizing performance mud motors and PDC bits were also an important item discussed in the meetings. Semi-automated driller (electronic driller) was a feasible way to improve ROP. Use of the pump pressure differential feedback created by on-bottom motor torque as the primary ROP control has been shown to be most effective in both directional and performance type mud motor drilling. This is especially true with slip-stick phenomena where ROP is sacrificed due to manually attempting to control WOB.

The use of a joystick disk brake system to allow proportional control was also agreed upon as the way to better control block speed, especially while running heavy drilling and liner strings with respect to control of surge pressures. As shown in top graph above, mud weights of 19.5 ppg and higher are anticipated in the Gotnia salt section with pore pressure/frac gradient extremely close, and lost-circulation problems, which usually require over a week to cure with associated concerns of well control.

The fine-tune control of the ECD surge, especially with a compressible diesel oil-based drilling fluid as used in deep drilling Kuwait, was deemed as critical for the maintaining of full returns during tripping and liner or casing running operations above and through the Gotnia.



Top: Anticipated mud weights of 19.5 ppg-plus drove the need for joystick disk brakes to better control block speed to manage surge pressures.
Middle: Rig substructure had to accommodate an 18 ¾-in., 15,000-psi BOP.
Bottom: A DC top-drive system was used.

MUD PUMPS

The possibility of drilling a very deep 25,000-ft exploratory gas well in Kuwait required a rig that could deliver more hydraulics in hole sizes even bigger than currently planned. Likewise, future deep directional delineation or development holes targeting intersection of vertical fractures in the Najmah/Sargelu formations required more than 5,000-psi surface pumping pressure to effectively drill with mud motors. For this reason, a comparison was made between 1,700-hp and 2,200-hp mud pumps used in conjunction with drill pipe sizes bigger than 5 in. As the figure to the right indicates, hydraulics availability increased dramatically with the use of 2,200-hp pumps with the added benefits of being able to run the pumps at lower speeds thus reducing wear and tear.

Also, if pump liner change-out was required due to wear and tear in the larger hole sections, the ability to continue drilling at optimum pump rate will be realized with two 2,200-hp pumps. With the 1,700-hp pumps in larger hole sections, the flow rate from two pumps must be restricted while working on the third mud pump.

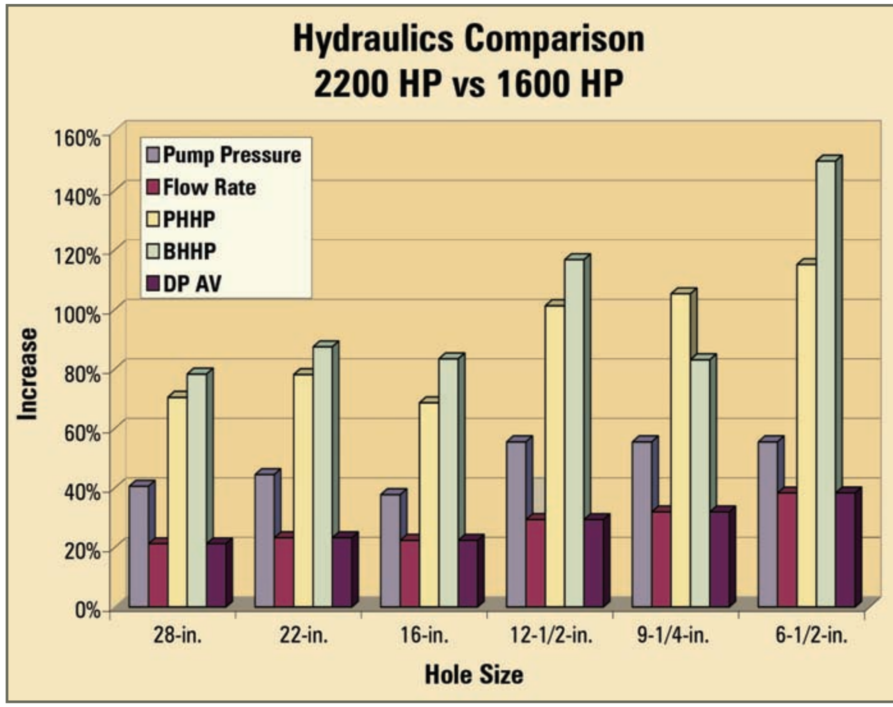
Rig floor iron roughneck – Safety was a prime consideration with respect to hand injuries during discussion of the iron roughneck as an addition to the newbuild rig. The ability to make up or break out various rotary connections at slightly different heights above the rig floor with more ease than traditional tongs, catheads and spinning chains has proven to be more time effective as well. The challenge with iron roughnecks has always been where to put them with regards to space and access on the rig floor. This is especially true where pipe is picked up offline and racked in the derrick while drilling hole, thus saving time and money.

It was decided to utilize a post-mounted hinge type iron roughneck to access both the rotary table for drilling/tripping connections as well as the mousehole for offline work.

In conjunction with the iron roughneck, the latest design power slips were installed for increased rig floor safety and to allow the running of many of the casing strings without the need to rig up casing slips that protrude above the rig floor.

MUD SYSTEMS

A KOC Deep Drilling Mud System Workshop was held in early 2004 with an IOC mud consultant to gain insight as to



Above: Hydraulics availability increases sharply with 2,200-hp pumps, compared with 1,600-hp pumps. Plus, the pumps can be run at lower speeds, reducing wear and tear. Below: Design of the driller's console was based on those of deepwater drillships and includes a voice-activated microphone to communicate with the rig floor.

solids control requirements and discuss various solutions for the newbuild rig. The consensus was for high-speed shakers with decanting centrifuges over traditional hydrocyclone equipment.

Discussions with several solids control companies confirmed this consensus. The number of shakers required for the largest hole sections was thoroughly researched, and consensus was to use four high-speed shale shakers for worst-case scenario in 28-in. hole section at 1,500 gpm. This was balanced with the realization of sizing the sand traps to the shakers and downstream plumbing troughs plus feed lines to take into account gas in the mud and other factors. A multi-flow diverter was also proposed to evenly distribute the mud returns from the flowline to each shaker to prevent overloading one or more shakers.

The solids control companies as well as mud companies were invited to visit a deep-drilling rig in Kuwait to gain insight as to what was unique about the fluids systems on these rigs and discuss what could be done to improve the capacity and handling requirements. Reducing the plumbing or dead volume within the pits and optimizing placement of processing equipment within the return flow streams was given top priority.

Reserve mud capacity was also discussed, especially with the requirement to switch from water-based mud to oil-based mud in the 16-in. hole section and problematic mud losses in the 16-in. and 12 ¼-in. hole sections. Agreement was to have at least 3,000 bbls of reserve capacity for the system for worst-case scenario, with a total mud capacity of 4,500 bbls.

Also discussed was the proper mix of valves and plumbing to access each compartment for manipulation of the system. Balance again was struck between too much plumbing and valves on the inside of the tank, which compromises space and useful volume versus not enough manipulation ability with reduced plumbing and valves. The size and weight of the tanks were also considered with respect to transport of same on Kuwait rig roads.

Finally, safety on the mud pits and around the solids processing equipment was detailed with such items as double grating (false upper deck) for reduction of trip hazards, mist system for cooling the people working on these pits during the hot Kuwait summers, and roofs over the pits for the same reason, included in the design. These were again balanced with issues such as weight/space limitations on rig moves, access to valves below the upper deck and safety concerns, plus safety glass fogging with the mist system in place.

Another important safety item with respect to the mud pits, especially with the use of flammable oil-based mud systems, was the agreement to install a dedicated foam deluge system on the mud pits to snuff out any fire break-out.

DRILL PIPE

In conjunction with the bigger pump design proposed, larger drill pipe was used to justify the anticipated hydraulics improvement in drilling. Especially for deeper deviated wells, the use of 5 ½-in. and 4-in. drill pipes has been proven to provide better hole cleaning and improved ROP via increased bit hydraulics. The use of premium high torque connections was also seen as critical to reduce NPT due to differential sticking by being able to apply more downhole torque to overcome sticking force. The bigger pipe sizes, although more costly, have proven themselves time and time again with respect to getting the hole drilled through problematic sections.

Items such as derrick finger space and handling equipment for these pipes had to be discussed with respect to racking capacity and TDS ease of pipe handling, change-out of jaws, etc.

BOP SYSTEM

On the other 3,000-hp deep drilling rigs in Kuwait, two separately sized BOPs are utilized in the drilling of the two different sized higher pressure sections of the well. Below the 18 5/8-in. intermediate casing, a 21 ¼-in. 10M BOP stack is utilized to allow drilling 16-in. or 17-in. hole section and passage of the 13 ½-in. casing string. This has consisted of two each 10M rams with a 5M annular on top. There have been wells drilled in Kuwait that have shown the requirement for a three ram stack, especially with mud losses and kicks in the same 16-in. hole section. This is difficult in the present 3,000-hp rig setup due somewhat to height restrictions as well as winching capacity of the BOP hoists beneath the substructure. The 12 ¼-in. hole section through the Gotnia utilizes a 13 5/8-in. BOP consisting of four sets of rams and an annular.

It was decided in the pre-planning of the HAH 124 rig to order an 18 ¾-in. 15,000-psi BOP stack configuration to allow placement of additional rams to reduce risk in well-control situations in the 16-in. hole section. Another important efficiency consideration in the selection of this stack was to reduce the nipple-up and nipple-down time by not having to change BOPs from 21 ¼-in. 10M to 13 5/8-in. 15M after the 13 1/3-in. casing is run and cemented in place. While it is true that the weight of the 18 ¾-in. BOP is higher, thus requiring bigger BOP winch capacity and more costs, it was felt that the cost savings were more than justified, comparing the advantages of a single 18 ¾-in. stack versus two stacks.

Advantages to the drilling contractor for a single stack in these hole sections include fewer spare parts. Disadvantages in this stack include no other rig having the same stack for interchanging parts if required, as well as more active hours over the well with respect to fatigue life.

OTHER DESIGN FEATURES

HAH Rig 124 design discussions also centered on several items based on past experiences within Kuwait Deep Drilling. The substructure was a sling shot type design with a cantilevered type mast, considered the most weight- and cost-effective for the high floor requirements given the BOP stack and HPHT wellhead stack-up. This type design allows for the ability to rig-up and rig-down with lower-capacity requirements and can be split up into easily manageable movable components for the rig move, an important consideration in the desert environment in Kuwait.

One feature on this rig, which is not on the other 3,000-hp rigs, is the addition of a sixth 1,450-hp engine. This provides a total available horsepower of 8,750, which gives increased flexibility of operation.

A Kelly was also maintained in the tender as a back-up for the TDS due to high torque encountered in the 28-in. and 24-in. hole sections in the deep wells that might have damaged TDS systems. This kelly system required modifications to the rig floor and substructure, allowing rathole space and a hook for the traveling block to latch the kelly.

The doghouse on the rig floor was twice the normal size for 3,000-hp land rigs in Kuwait. This doghouse was air conditioned by large roof units and can comfortably accommodate the entire drilling crew for safety meetings prior to critical jobs where proper noise level is essential to hear the details. The driller's console was chosen similar to those seen on deepwater drillships, with voice-activated microphone to communicate with the rig floor.

Larger rig site trailers with increased office and sleeping quarter space, fitted with the latest specification computer and communications equipment, increased comfort for rig personnel.

BUILDING AND INSPECTION

Once the design and tender were finalized, the construction of HAH 124 began in earnest in mid-2004 under the direction of **National Oilwell** in Edmonton, Alberta, Canada. While the substructure, derrick, power train, SCR, semi-automatic controls and mud system were being built Edmonton, the top drive system was being constructed in Norway, and the 18 ¾-in. 15K BOPs were being built in France.

Hamad Al-Hamad hired several key drilling and rig building personnel to monitor the progress of the construction in Canada, with a major issue being proper meshing of the TDS system in Norway to the rig power and electrical system in Canada. Likewise, fitting of this torque tube design TDS provided major challenges to the final overall design of the derrick, and changes were required during the actual building phases to allow easier rig-down and rig-up with respect to electrical connections.

Progress reports were sent on a periodic basis from the rig builders to HAH and KOC with time estimates for completion. Third-party inspection and pre-commissioning of the rig was also planned in Edmonton prior to shipping the rig to Kuwait for assembly. Delays were encountered primarily due to obtaining the prime movers for the rig and due to an increase in requests for drilling rigs in this time frame, which in turn caused delays in equipment arrival and stretched out rig-building personnel.

The original construction planning included mating of the TDS and derrick in Canada, as well as commissioning the entire system together prior to shipment to Kuwait, but delays in Norway prevented this from happening. Therefore, plans were changed to assemble the TDS onto the derrick in Kuwait on the initial well.

A team of KOC deep-drilling representatives met with the third-party inspectors as well as HAH personnel and National Oilwell rig builders in Edmonton at the end of January 2005 to finalize pre-commissioning plans and inspection procedures. The derrick was raised and preliminary inspections performed on the rig without the TDS, which remained in Norway.

There were some issues concerning pre-commissioning with such items as full-load testing of the mud pumps within the National facility due to safety regulations, but most of these were discussed and resolved in daily meetings. The rig was impressive in terms of size, power and pumping capacity with the big question the mating and operation of the top drive.

The hiring of some HAH drillers and toolpushers was also done prior to the rig building to allow as many key people as possible who would run the rig to be in the rig-building process. This was also a challenge with respect to the upturn in the drilling industry with the price of oil.

TRANSPORT AND RIG-UP

HAH 124 was shipped from Canada in the spring of 2005, and rig-up began under the trying Kuwait desert summertime heat. As the rig was being assembled on the initial well in southeast Kuwait, HAH rig personnel were being hired with increasing difficulty due to the oilfield drilling boom now in full swing.

The rig-up of HAH 124 was a slow and tedious process for several reasons, including the complexity of the semi-automatic control system and unfamiliarity of this new rig to the contingent of new-hires. A team of National Oilwell rig-building experts worked on the more complex parts of the initial rig-up, as well as training the newly hired electricians and mechanics.

The marriage of the Norwegian-built TDS system to the rig electric power and fit into the derrick was probably the biggest single issue during the rig-up on the initial well. This was not totally unexpected with the difficulty in accurate communications of technical requirements and dimensions from long distance versus being there to actually witness the meshing at the rig-building yard with access to better infrastructure and technology.

The main problems with the TDS system were:

1. Mating of electrical power with the control system.

2. Reducing the overall length of TDS and block assembly to allow safe working distance below crown.

3. Fitting of additional supports and torque arrestors to the TDS torque tube.

4. Link tilt and pipe-handler systems.

5. IBOP functioning.

Other problems during this period were mainly electronic/software ones affecting the drilling instrumentation, power assignment and auto driller controls.

COMMISSIONING

Commissioning of HAH 124 was completed in October 2005, and the first well spudded on 10 October 2005. The initial well was a vertical exploratory Jurassic test with moderate difficulty in the high-pressure sections of the wellbore. The well was successfully drilled to a depth of 14,260 ft in 152 days and made an exploratory discovery in the Marrat formation. The well timing was reasonable compared with the initial well that KDC Rig 15 drilled in 2004, especially considering that it was the first deep HPHT well ever for HAH using a new high-tech rig with new drilling crews.

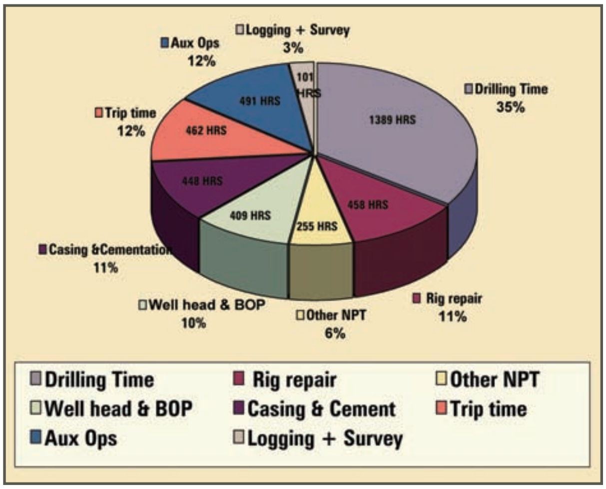
Drilling time analysis is shown in the figure at right, with the breakdown of NPT time due to rig repair at 11%.

The rig was found to have the usual bugs associated with all newbuild systems, and several are still being rectified as drilling on the second well progresses. For the desert environment in Kuwait, several items built in Canada were not adaptable to the heat and sand and therefore changed out, including:

1. Mud pit external tank dump valves – leaking.

2. Air conditioner for the doghouse and SCR – inadequate output for Kuwait heat.

3. Various electrical connectors to SCR and rig motors, instrumentation and equipment – inadequate due to heat and sand.



NPT for HAH Rig 124 for rig repair was 11%.

In all, performance of the rig equipment shows indication of being top-class in the 3,000-hp field once the various issues with electronic connections, software for the automatic drilling function computers, and final sensitivity between the electric system and TDS are fine-tuned.

The mud system is performing as planned, and solids control is not an issue with the high-speed linear shaker system. Some adjustments were made in plumbing to prevent aeration to the drilling mud and cavitation to mud pumps with suction valves too close to discharge in the pits.

LESSONS LEARNED

1. The most important lesson learned is to build or mate the entire rig system, including top drive, at the rig-building yard and to perform the final commissioning at that yard with the improved infrastructure and technical expertise available.

2. The second most important lesson learned is to hire and, more importantly, maintain the key drilling people for a rig such as HAH 124 from design discussion to the actual drilling of the first well. The oilfield boom had a very adverse impact on continuity of the key electronic technicians and electricians who are required to understand and maintain the semi automatic control system and electronics. Mechanics were a close second to the key people who came and went with better offers each month.

3. The TDS design would be better as a track design versus a torque tube as built due to ease of rigging up and rig-

ging down, and also ease of parking the top drive. Vibration has also been an issue with the torque tube. The IBOP and pipe-handling functions and change-out of same on the HAH 124 TDS have been problematic from the start and a different built system should be considered. Changing out wash pipe has been a challenge due to lack of easy access point.

4. The TDS system might be better if designed for making connections 15 ft off bottom using a guide racking grip, as on many offshore drilling rigs. This will allow less risk in freeing up differential sticking on connections by being able to work the torque down off bottom.

5. The doghouse requires a better line of sight from the driller to the entire rig floor as the window does not extend far enough down to permit view of the rig floor immediately adjacent to the driller. The drilling communications system is difficult with the various nationalities on the rig floor with limited English proficiency.

6. The plumbing between mud pits was designed too rigid, which caused initial problems in rig up with fitting same.

7. The 18 ¾-in. BOP stack worked as anticipated and, with a little more planning, will prove itself more cost-effective than the two stack system being used on other deep-drilling rigs in Kuwait.

8. The 2,200-hp mud pumps have not been put to the full test with 7,500-psi rating but are proving themselves as one liner size is possible for the entire hole (if desirable), and drilling the 28-in. hole has not been adversely affected due to liner change-out since the same gpm can be use with two mud pumps.

9. Training on the semi-automatic control system should be performed during the rig build with the drillers as this system takes more time to get used to compared with the band brake system. This is especially true for operations such as slipping and cutting drilling line.

10. A dedicated task force for the newbuild rig from both KOC and the proposed drilling contractor solely dedicated to this task should be considered for future rig builds. This could include a contracts person with technical background to expedite contracts questions.

11. Retaining a kelly in case of total TDS breakdown, especially in the 28- and 24-in. hole sections, where severe rig vibration occurs even with shock subs, had not required and resulted in problems with spacing of the rig mousehole and resulting ease of BHA connections while picking up same.

12. The other problem that occurred due to the design of a back-up kelly into the rig was the use of a hook on the traveling block that resulted in lack of clearance for connections while running cementing strings inside the larger casing with the false rotary rigged up. An adaptor (Becket) was ordered to connect the TDS to the traveling block after the rig was put together in Kuwait to allow more space for these connections.

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