Artist's impression of the CAN-DO drillship.

DESIGNING the Next Drillship

How Keppel sees exploration, development, and completions in ultra deep water

BY THE KEPPEL CAN-DO DRILLSHIP DESIGN TEAM

The oil and gas value chain starts with discovering of fields, followed by exploration, development, and completions of these fields. The oil and gas recovered from the field undergoes production, shipping, and refining before being transformed into end products such as gasoline, diesel fuel, and lubricants. These are extracted by the oil refineries along with plastics and fertilizers, which are made by the petrochemical industries.

Oil and gas are produced from special rocks called reservoirs. Over time, the organic matter buried deep in the earth changes form to become hydrocarbons. These reservoirs can be underneath dry land or water. To recover these valuable hydrocarbons, drilling is necessary.

The first step in the process of extraction of oil and gas is to find the well location, which can be identified by interpreting magnetic and seismic surveys. This phase is known as exploration. Once the tentative location of a well is identified, a well is drilled to determine if the proposed location indeed has a fair amount of hydrocarbons. This phase is known as exploration drilling.

If large quantities of hydrocarbons are found, appraisal wells will be drilled to determine the size of the field. After this, the wells are developed and this process is known as development drilling. During this process, a well is drilled in a proven area to ensure that a fair amount of hydrocarbons are available in the reservoir and that it is beneficial to complete the well. A development well is drilled to a depth that is likely to be productive, so as to maximize the chances of success.

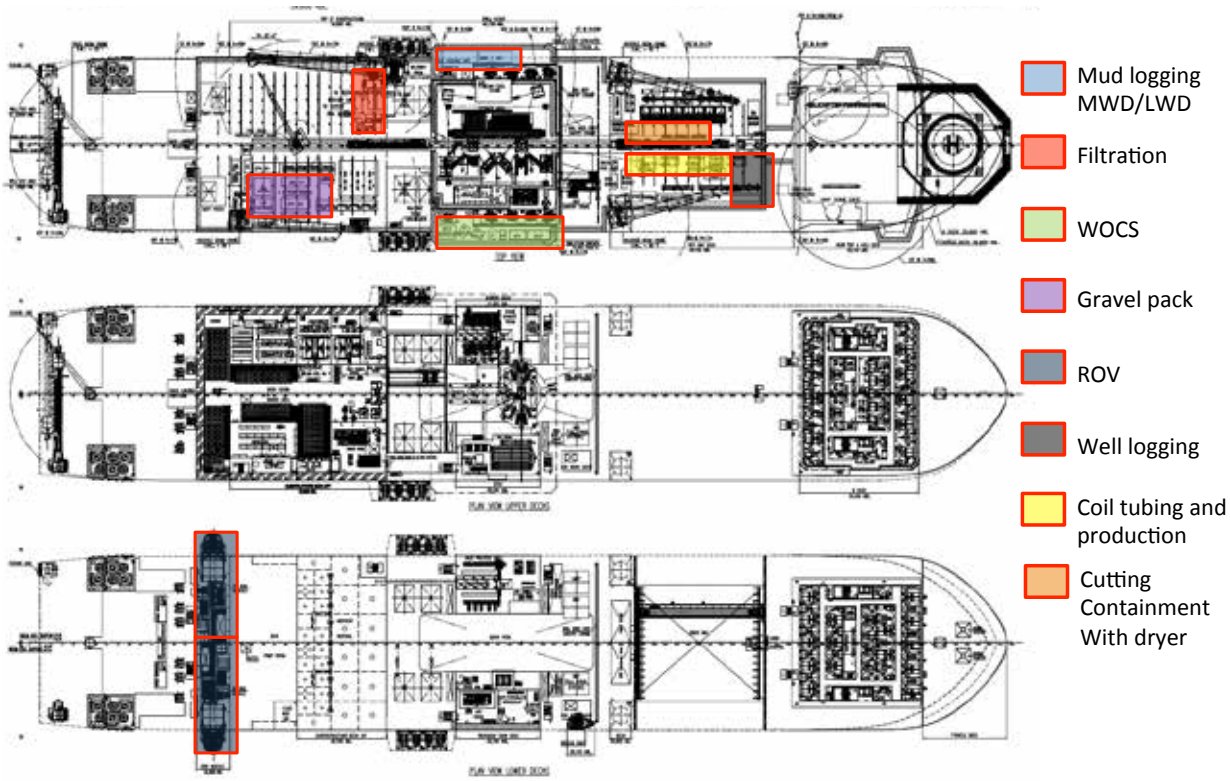
After the wells are developed, the process of making a well ready for production is known as completions. The operator must provide a way for the reservoir fluids to enter the well and reach the surface. For the most part, this involves perforating the well and enabling, by natural or artificial means, the reservoir fluids to enter the well through the perforations.

The right rig

In all of these processes, the importance of choosing a rig cannot be overstated. The parameters considered in choosing a rig type are operating water depth, deck load carrying capacity, and environmental condition.

A drilling contractor may choose a bottom-supported unit (jackup or submersible) or a floater (drillship or semisubmersible). A jackup is suited to shallow water operation, whereas floaters are the rigs of choice for deep water operations (350 ft. and beyond).

A semisubmersible exhibits good motion characteristics and is suited for deep water and



Third-party layout on upper decks.

harsh environment such as the North Sea, whereas a drillship is suited for deep water and not so harsh environments, such as the Gulf of Mexico. Owing to their high load carrying capacity, drillships are suited especially for ultra deep water (UDW) operations in locations 350 km and further off the coast. Thus it comes as no surprise that drillships have become the rig of choice for drilling contractors involved in these applications.

Exploration, development, and completions operations require different features owing to the different expectations from the drillship. The primary functions carried out by a drillship are the drilling of exploration and appraisal wells, and the drilling of development wells.

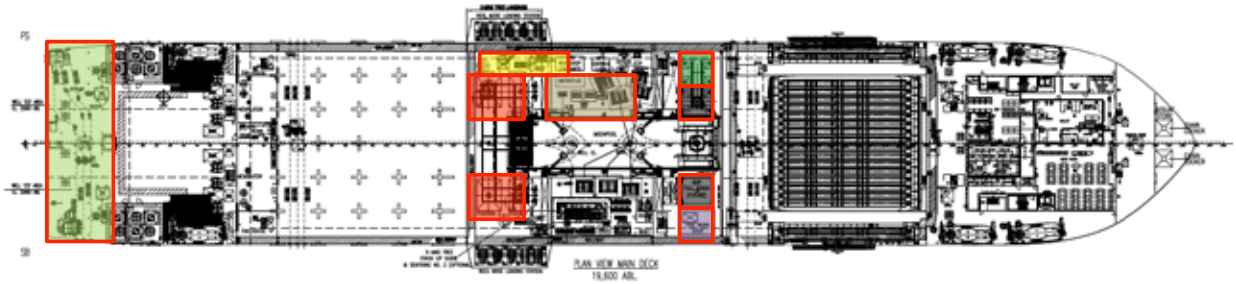
Exploration and appraisal wells (drill plus data acquisition plus test). These make up the first set of wells on a prospect. The primary objective of these wells is to evaluate the potential commerciality of hydrocarbon accumulations. Data acquisition is critical to gaining an understanding of the different formations and fluids present; therefore, it is typical to perform wireline logging and coring. If hydrocarbons are discovered, an operator may decide to flow the well back to the surface by running a temporary completion connected to a testing package. These hydrocarbons need to be flared off or collected and disposed of. Exploration and appraisal wells are usually abandoned once they are drilled by isolating them from the reservoir with cement.

Development wells (drill plus complete). If exploration drilling confirms viability of commercial hydrocarbons, then a series of development wells are drilled to extract these hydrocarbons. Development wells also may include water and gas injectors, which provide pressure support to the produced reservoir. Drilling is normally quicker due to the fact that pore pressure, fracture gradients, and formation changes are already known to some degree.

A key difference with a development well versus an exploration/appraisal well is that a completion is required to allow the hydrocarbons to flow to the surface, or fluids to be injected downhole. Completion design can vary considerably but will likely contain a tubing string and packers, and also will require a Christmas tree to be installed on the wellhead, which allows the well to tie into production infrastructure (for example, a subsea production manifold).

Keppel's answer

Our CAN-DO drillship is designed to carry out exploration, development, and completion operations. Designated arrangement and allocation of deck space is made for third-party equipment to support development and completions drilling. Due consideration has been given to functionality, accessibility for maintenance, operability of equipment, and safety while working with third-party vendors.



Christmas Tree
Well test
MPD equipment
BOP full stack
LMRP
Pod test stand
Cutting collection with skips

Third-party layout on main deck.

Specialized equipment for well testing, managed pressure drilling, coil tubing and wireline units, dual gradient drilling, and workover and control systems (WOCS) have been accommodated.

Having deck space is one thing; the ability to load the deck space so that the vessel can carry a variable deck load (VDL) is another. Keppel's CAN-DO is designed to carry a VDL of 32,000 metric tons, as compared to similar drillships that have VDLs in the range of 20,000 to 25,000 tons. A number of challenges were overcome in the design of this drillship.

Deck space

CAN-DO has been designed with highly functional deck space for its role in development drilling and completions drilling. A number of features help achieve this deck space.

An additional well test deck on the aft of the ship is designed to provide enough space for third-party equipment. The well test deck is designed to sustain a distributed load of 5t/m^2. The elevation of the deck is such that the mooring winches are housed beneath it, and enough space is provided for running of cables and pipes.

The funnels of the vessel are split on the aft deck, with one funnel on the port and one on the starboard side. The split funnels make the aft deck more accessible and provide greater functionality in using the deck space.

The forward thrusters are retractable into the hull. This feature makes the full deck available above the thrusters, with a soft patch large enough for replacement of the thruster motors. The aft lifeboats are protected by platforms above, a feature beneficial not only from a safety point of view but also in terms of usable deck space.

The pipe rack above the riser bay is designed to have an elevation sufficient to facilitate a clear path for coiled tubing equipment on the deck. The ROVs are housed inside the mud module above the main deck; this feature saves valuable deck space by not allocating additional deck space for the ROVs. The pipe rack deck, above the mud module, makes space for third-party equipment to provide greater functionality.

Extended platforms are provided on the port and starboard side of the drillfloor to facilitate transfer of materials from forward to aft and vice versa; the platforms also accommodate third-party equipment on this platform.

Mud module and transfer system

The CAN-DO design has a mud module consisting of the high-pressure mud pumps, sack storage, and mud mixing and supply for easier access and operability. Mud charging pumps, mud mixing, and mud additive systems, as well as mud pits in the mud module, are all integrated in close proximity to shorten the pipe length and transfer path to enhance the overall efficiency of the mud system. Containment of the entire low-pressure and high-pressure mud system outside the vessel hull results in an additional level of safety, such that any incident relating to these systems does not compromise the integrity of the hull.

The bulk material tanks are located directly below the mud module and adjacent to the bulk loading station. This results in efficient bulk transfer rate from the loading station to the bulk material tanks and from the tanks onto the mud module. This enables the full benefits of an efficient system design to be realized for an overall improved performance of the mud system.

Suitability for UDW operations

During UDW operations (300 to 400 km off shore), managing logistics for the drilling rig is of prime importance. The following features come in handy while operating in UDW conditions.

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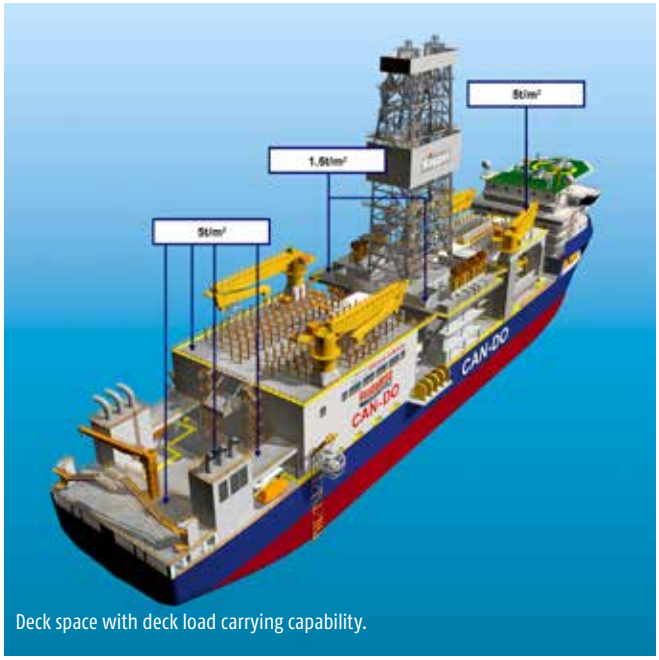
High tank capacities. The CAN-DO ship has much higher tank capacities compared to the existing fleet of drillships. All the mud capacity on the CAN-DO design has been provided in the mud module, which allows hull tanks to carry other consumables. The vessel is designed to carry 10,000 m^3 of fuel oil. High fuel oil capacity enables fuel autonomy, which permits the vessel to transit from Southeast Asia to offshore Brazil or the Gulf of Mexico without any need for bunkering along the way. During the operating condition, this capacity reduces the frequency of supply boats, which results in non-productive time, because during bunkering, no hot work is allowed to be carried out on the drillship. This feature has been achieved by iteratively going through the design process to ensure there is sufficient ballast capacity for the entire operating envelope. High tank capacities enable long drilling campaigns without having the need for replenishment, thus reducing operating costs.


Split funnel, well test deck, and covered aft life boat on CAN-DO.



Deck space with deck load carrying capability.

Stability and longitudinal strength. The stability of the vessel is analyzed, bearing in mind the various drilling cases such as exploration, development, and completion. This gives the flexibility to choose the right amount of mud, brine, and base oil combinations to suit the specific drilling scenario. The stability of the vessel is analyzed with two basic cases: one that maximizes the combined hook load as in the drilling scenario, and another that maximizes the setback load as in the start of the running casing scenario.

The 30,000 barrels of mud carrying capacity represents one of the biggest challenges in analyzing the stability and longitudinal strength of this vessel. The main drilling consumables (the mud and the brine) are arranged in such a way that the brine tanks are below the mud pits to minimize the piping. However, the huge loads of mud and brine coming in the same location poses the problem of large still water shear forces and bending moments. The vessel has suitably positioned water ballast tanks, so that redistribution of the ballast water can be done to minimize the shear forces and bending moments.

One of the main features of the ship is that it will be able to keep the same draft while in operation when the consumables (marine and drilling) are reduced to near zero percent (zero VDL) so as to allow the vessel to operate for extended duration without replenishment of supplies from supply vessels. This creates another challenge in the water ballast capacity and the tank positions. The tanks are arranged in such a way that the water ballast tanks adjacent to the consumables tanks are approximately sufficient enough to counter balance the reduction in the consumables, so that not only the vertical center of gravity (VCG) is controlled but also the shear force and the bending moment distribution of the vessel.

The mud pits above the main deck is a feature that has been adopted to keep the mud system separate from the hull, and the interface creates an efficient mud circulation solution. The high mud VCG is compensated by having low VCG of the brine tanks and the drill water tanks in the double bottom space.

The ocean transit case is optimized to carry the maximum amount of VDL. The vessel is designed to maximize not only the drilling consumables but also the marine consumables, considering all the possible scenarios of operation in its lifetime. Every operation scenario is analyzed with a survival mode situation in mind.

Retractable thrusters. The forward thrusters are retractable. Once retracted, they are above the keel line, and the aft thrusters, although non-retractable, are also above vessel keel line. This enables the vessel to come along quay side for repairs, change of crew, and taking on of supplies, and to access a dry dock.

Motion characteristics and seakeeping. One of the criteria for designing the modern day drillship is the ability to accommodate

CAN-DO underwent model tests at the MARIN facility in the Netherlands.

off-the-shelf drilling equipment, which represents the most expensive components of a drilling rig. This requires ensuring that the vessel motion performance lies within the operating range of the equipment. To meet the drilling equipment capabilities, the designers have to suit the seakeeping performance of the vessel to the ocean environment. The fundamental parameters that define the seakeeping performance of ships are the heave, pitch, and roll natural periods.

The heave natural period is a function of three parameters: block coefficient, waterplane coefficient, and draught. The heave natural period for the most seagoing ships is between 7 and 11.5 seconds. The pitch natural period is purely a function of the length of the vessel. Similar to the heave natural period, the pitch natural period for the most seagoing ships is between 6 and 11 seconds.

Development wells also may include water and gas injectors, which provide pressure support to the produced reservoir.

In contrast to pitch and heave, the roll natural period can be adjusted during operation as it depends not only on the hull form but on the loading condition as well. These tight limitations for pitch and heave natural periods rapidly decrease the seakeeping flexibility of the seagoing ships. On the other hand, the marine environment itself is the other important factor in the drilling profit and efficiency equation. In terms of wave energy, more than 95% of the waves in the world's oceans have periods between 4.5 and 10.5 seconds. This range is commensurate with the heave and pitch natural period ranges. This similarity is the key challenge for all drillships, as a lot of additional accelerations and motions are induced during the ship-wave interaction because of it.

Trying to avoid this intersection is not an option for any drillship designer because, although this may be one important factor, it is not the only one. For improving the seakeeping performance of a drillship we need to look into the hull size and hull form details such as moonpool shape; bulbous bow shape; stem angle; transom immersion; and the bow and stern flare angles.

We cannot escape from wave energy if we try to move in a horizontal direction. The only solution, therefore, is to try to move vertically. For this purpose, we need to ensure that our drillship will not be excited by waves with heights up to 3 m; or we can at least try to reduce this excitation as much as possible. We know that the energy that each individual wave is carrying is a quadratic function of its height. Further to that, by increasing the vessel size we also are increasing its inertia, which reduces the dynamic response amplitude, especially when the excitation energy is small.

The CAN-DO transit speed of 13 knots (with 6 thrusters), despite its big moonpool, is achieved by optimizing the moonpool size and shape to minimize the added resistance. The oscillations of the water column inside the moonpool are the major cause for this additional resistance. The moonpool shape defines the well-known piston and sloshing resonant modes with associated frequencies. During the design of the vessel, various moonpool parameters were optimized for minimal sloshing amplitude for Froude numbers between 0.10 and 0.15.

Dynamic positioning system with DP3 capabilities. Dynamic positioning with DP3 (DP3 signifies compliance with most stringent ABS criteria on fault tolerance) has been the best suited stationkeeping solution for drillships in deep water. CAN-DO is equipped with six azimuthing thrusters—3 forward and 3 aft for maintaining station and heading. The thrusters deliver open-water thrust of 1017 kN at an input power of 5500 kW with zero inlet velocity, which enables the ship to keep position and heading.

Dynamic positioning analysis for the drillship for the design environments of the Gulf of Mexico, offshore Brazil, and West Africa shows

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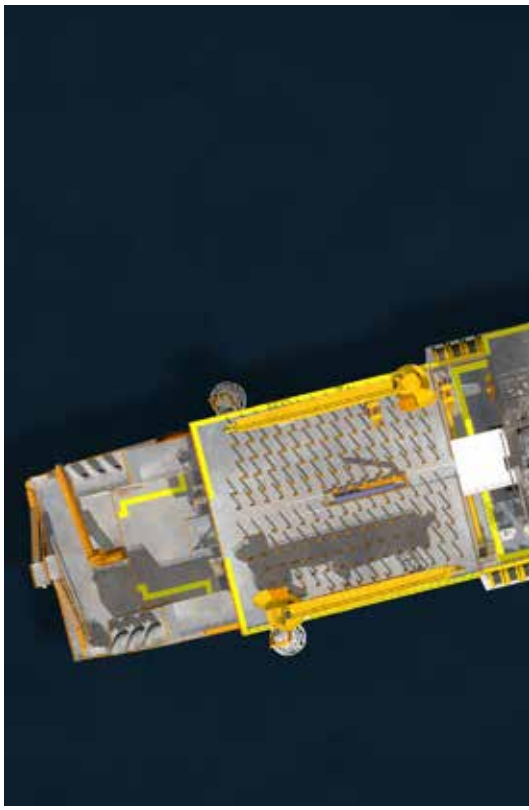
This view of the bow of the vessel shows the helideck layout, with extra helicopter parking space, and recessed lifeboats.



that the vessel has sufficient power to maintain station in intact and two thruster damaged conditions. Collinear environment (loading from wind, wave, and current coming from the same direction) is considered as this gives the worst environmental loading on the vessel. A weathervaning window of +/- 22.5 and +/- 15 degrees is considered for intact and damage cases respectively. The maximum use of a single thruster is capped

On the drill floor, space has been provided for future upsizing to 20K choke and kill manifolds.

at 80% and the remaining 20% power is reserved for dynamics. The maximum use also includes the losses from thruster/thruster and thruster/hull interaction.

The maximum static thruster use is kept less than 80% for two thruster damage cases. Loop current case was also considered as Gulf of Mexico experiences loop current conditions. Due to the high magnitude of current loads, the vessel is allowed to align itself to the current, and the maximum offset of waves and wind (collinear) is determined. Analysis showed that the wave and wind can have an offset of +/- 60 and +/- 30 degrees from the current for intact and damage cases respectively.

20K equipment design ready. With operations moving towards UDW, the industry is looking towards 20K psi rated drilling systems. Keeping the future in mind, the CAN-DO vessel is designed to be 20K psi drilling system ready.

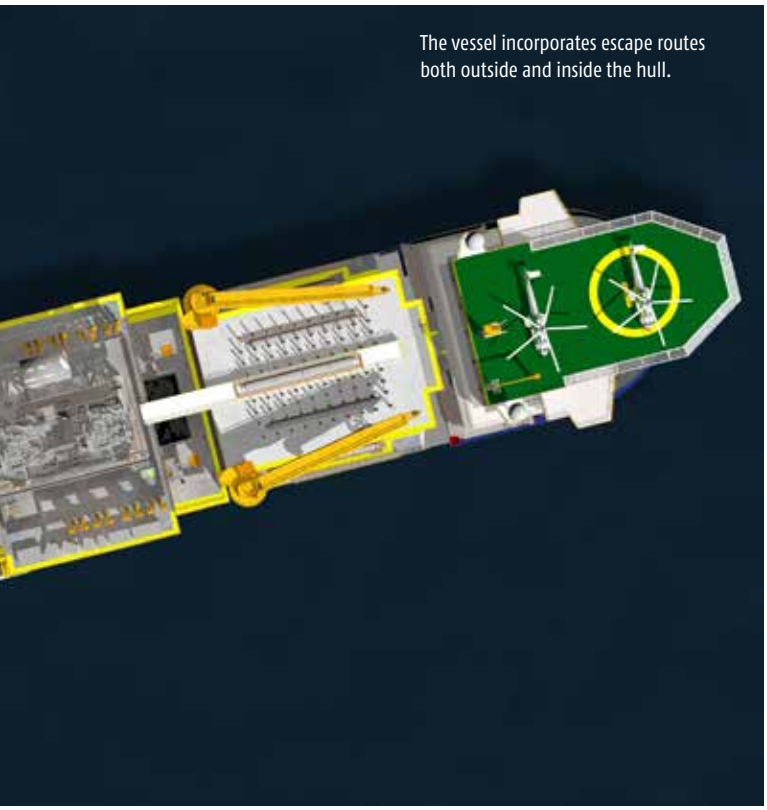
Based on extensive consultation with drilling equipment vendors and market demand, the drill floor and moonpool deck areas are designed to support 20K drilling equipment such as a 20K blow out preventer (BOP) stack, a higher capacity of BOP gantry crane, a 20K choke and kill manifold, and so forth. The high drill floor elevation enables a 7-ram or 8-ram 20K BOP stack height to be accommodated and the hull foundation is designed to support the weight of a 20K BOP full stack.

The moonpool trolley's rail foundation was designed to cater to a future upgrade to a higher capacity of trolley. Space provision for a 20K subsea control system also has been provided to support the future 8-ram stack.

On the drill floor, space has been provided for future upsizing to 20K choke and kill manifolds and for a higher-capacity mud gas separator to meet 20K drilling system demands. For use in 20K drilling operations, the riser hold was designed to store up to 12,000 ft. of 62 in. OD riser with buoyancy module without requiring any modification of the hull structure.

Safety first

To ensure crew safety is of paramount importance for a rig, especially during UDW operations. The rig has been designed in compliance with ABS HAB+ (which signifies compliance with ABS criteria on crew



The vessel incorporates escape routes both outside and inside the hull.

living and working spaces) notation. This ensures improving quality of personnel performance and comfort, improved accommodation area design, and improved ambient environmental qualities. Brazilian standard compliance ensures wider escape routes and widened walkways and stairways, among other standards for safety.

The following features have been incorporated in the CAN-DO ship design to ensure crew safety and comfort.

Escape routes. The vessel is designed with inherently embedded escape routes within the hull. These escape routes also double as dedicated DP3 utility channels and serve to provide a maintenance and access platform for DP3 utilities such as piping, ducting and power, and control cable trays.

In addition to the escape routes in the hull, the ship also provides for escape routes on the periphery of the main deck and the drill floor elevation. There is also a provision of direct access from the office deck in the living quarters to the working areas inclusive of drill floor, mud module, and so forth.

Helideck. Compliance with CAP – 437 (United Kingdom civil aviation standard for offshore helicopter landing areas) has become industry standard for operations in UDW. The helideck on the CAN-DO ship is designed to enable a wide range of helicopter types to land, up to an Mi-8. With the roof at the top deck and the helideck having the same elevation, a parking area was allocated to facilitate stowage of a broken down helicopter, at the same time not causing obstruction for a functioning helicopter to land.

Blast wall. Based on operator requirement, the CAN-DO living quarters structural design has incorporated a capability to withstand a blast load of magnitude 2 bar @ 100 msec coming from the drillfloor towards the living quarters. The blast wall is thus inherently embedded into the living quarters structural design, which ensures protection of the living quarters and forward lifeboats from any explosion originating from the drillfloor that may jeopardize the safety of the personnel. The living quarters windows can be provided with blast-resistant glass.

Forward and aft lifeboats. The forward lifeboats are recessed so as to protect them from any green water splashing, and the are protected by a blast wall on the aft side. The aft lifeboats are covered from the top by a platform and thus provide protection.

Accommodations

To cater for development and completion operations, high crew carrying capability is of prime importance. The CAN-DO vessel is designed with a capacity of 220 crew members (including third-party personnel). While designing the living quarters, functionality and safety consideration have been given highest priority. A helideck pedestal crane has been provided to access the helideck as well as the landing area in the accommodations unit. The accommodations unit was designed in compliance with ABS HAB+ (MODU) notation and provides generous space and is designed for crew comfort. Injured crew members can be landed at the hospital, which features doors large enough to accommodate a stretcher.

On the horizon

Demand for floaters is expected to be strong in the coming years as development drilling would drive the next leg of rig demand—arising out of the success of recent exploration drilling campaigns—which would then transition into the development phase. There also is a strong case for fleet renewal, as operators would be looking for modern equipment based on stringent regulatory scrutiny in a post-Macondo regime.

Also, recently-delivered rigs are showing much higher unplanned downtime due to equipment hiccups as well as teething problems associated with prototype rigs, while older rigs are inherently less efficient. This unplanned downtime also translates into a need for a larger pool of rigs, as this would mean a larger amount of time required to drill the same number of wells. In addition, there is a shift toward more challenging well operations due to increasing well complexity in greater water depths.

Against this backdrop, the oil market will be able to absorb additional newbuild drillships for delivery from 2016 through 2020. There also is a likelihood of demand from Mexico towards the latter half of this decade, especially if energy reform proposals are successful. Add to this the demand for drilling rigs for offshore Brazil, driven by demand both from Petrobras and a broader base of other operators. We also could see demand for drillships from frontier regions such as east Africa and the Black Sea.

We believe that our CAN-DO vessel would be able to provide cost-effective and adaptable solutions for exploration, development, and completion operations, both in deep water and UDW environments. **MT**

The Keppel CAN-DO design team *is based at Keppel Offshore and Marine Technology's Singapore facility.*