Introduction

This chapter will discuss floating mobile offshore drilling units (MODUs), their equipment and how to operate them. At this writing (Q1 2015) there are more than 900 MODUs of all types in the world, more than 300 of which are floaters (nearly 200 semisubmersibles ["semis"] and more than 100 drillships). This chapter will not cover bottom-supported units (jackups and submersibles), stationary platform rigs, or tender assist drilling (TAD) units.

The first offshore well was drilled in Louisiana in 1947, followed in 1955 with the first well drilled from a floating vessel using a blowout preventer (BOP), a landmark that occurred on the California ocean floor. Since these milestones, equipment and processes for drilling from floating vessels have grown enormously and now constitute some of the most sophisticated technologies in the world. Two key characteristics of a floating drilling rig distinguish it from an onshore or bottom-supported rig. The rig:

- Is fixed over the well by a spread-mooring system or a dynamic positioning (DP) system ("stationkeeping");
- Drills through a pipe (marine riser) connected to a BOP stack that is latched onto a wellhead at the sea floor. (Surface BOP drilling, which is discussed later in this chapter, is an exception.)

Today's floating MODUs are generally categorized by water-depth capability as follows:

- Shallow-water units (less than 2,000 ft water depth) are almost all spread-moored semisubmersibles, with a few drillships built prior to the early 1990s;
- Intermediate, or midwater, units (2,000 ft to approximately 7,500 ft) are a mix of upgraded and new spread-moored and DP semisubmersibles and a few DP drillships;
- Ultra-deepwater units (more than 7,500 ft), of which a majority are DP drillships built since the late 1990s. At present no MODU is rated beyond 12,000 ft water depth.

Drilling rigs being built for ultra-deepwater are DP drillships or semis. Today's MODUs are built to a standard and certified by Classification Societies, regulated by industry organizations and "registered" in a country just like a commercial vessel. In the United States for example, the US Department of the Interior regulates the wellbore and the US Coast Guard regulates the MODU. The classification agencies and governments work together and have a powerful influence on MODUs and their operation.

Higher cost and risks also differentiate floating from bottom-supported drilling rigs. As of the mid-2010s, construction costs for an ultra-deepwater MODU average $700-$750 million, with some units as high as $850 million. Dayrates for these MODUs can reach $850,000/day, with total operating rate, including all support services and expendable items exceeding $1,500,000/day. As a result, $100-million deepwater wells are common. Some have exceeded $250 million in cost. Assuming an economic hydrocarbon discovery is found in deepwater, the development cost can be tens of billions of dollars, with a 5-10-year horizon for first production. This extremely high capital cost leaves most floating drilling and development to major oil companies, though some independents do conduct floating offshore operations.

Figure FD-1: Unlike land or bottom-supported offshore drilling, floating drilling rigs are fixed over the well by a mooring or dynamic positioning system and drill through a pipe connected to the BOP on the wellhead on the sea floor. Courtesy Diamond Offshore Drilling Inc.

It has taken the industry more than 50 years to develop the technology to drill economically in deepwater. Compared to the first floating drilling units, today's deepwater rigs are significantly larger, with water displacements reaching 90,000 deadweight tonnage (dwt) and beyond. (Deadweight tonnage represents how much weight a vessel can safely carry, totaling weights of cargo, fuel, freshwater, ballast water, provisions, passengers and crew.)

Today's floating rigs can also drill much deeper, with wells reaching 40,000 ft in depth. (This is the depth of the well, not the water depth, which is a separate measure.) Hoisting systems must handle loads in excess of 2 million lb to run and pull the marine riser and BOP stack. Subsea BOP stacks are generally rated for 15,000 psi, can weigh more than 600,000 lb, and are well over 40 ft tall. Marine riser tension systems to structurally support the riser with proper drilling angles might require pulls beyond 4 million lb.

Another complicating factor for offshore operations is the variable met-ocean environment (winds, waves and currents), which impact the motions of the MODU. Met-ocean conditions can add significant loads to the stationkeeping

system, whether moored or DP, and complicate supplying the rig with expendables.

Weather can also be problematic. Arctic conditions can cause ice loading, and icebergs can force rig moves. Spread-moored MODUs are often temporarily abandoned for safety while a hurricane or cyclone passes. DP vessels, however, can often move away from storms. The North Sea, Gulf of Mexico, eastern Canada and the west coast of Australia can suffer some of the most severe met-ocean conditions for MODU operations. Even in good weather, supplying the floater, usually far offshore, can be a challenge because of lengthy boat and helicopter transit times. Foul weather further complicates water and air transportation, especially for loading or offloading supply boats in rough seas.

Because of the impacts of distance and met-ocean conditions, offshore wells typically take longer to drill and in some cases to complete than onshore wells of similar types.

Another complication in floating drilling is reduced fracture gradient, the level at which drilling fluids crack the rock and flow into the formation. This is because the confining pressure of the rock, acting as a barrier to fluid inflow, represents a combination of not only the rock, but the weight of seawater acting on the sea floor. For example, a 10,000-ft well in 5,000-ft water depth has a confining pressure composed of the weight of 5,000 ft of rock and 5,000 ft of water. Conversely, a 10,000-ft onshore well has a confining pressure composed of the weight of 10,000 ft of rock only; thus the well in 5,000 ft water depth has a lower fracture gradient. The deeper the water and the higher the mud weight needed to control formation pressures in the well, the greater the likelihood of fracturing the formation, resulting in a wellbore stability and/or a well control issue. In conventional (i.e., non-managed pressure drilling or non-MPD) drilling operations, the only solution to low fracture gradients is to run more casing in the well to cover weaker zones. Because of reduced fracture gradients, it is not uncommon in deepwater wells to need 7-9 different casing strings to drill the same depth for which an onshore well might require only 3- 4 casing strings.

"Subsalt" drilling is a further complication in deepwater. Such wells are drilled through thick salt lenses, often into unknown pressure gradients below the salt. Abnormal pressures are common in deepwater drilling, especially in the Gulf of Mexico, and the combination of high pressure and high temperatures (HPHT) in the wells increase the difficulty in drilling safely and successfully.

These severe environments, abnormal pressures, ultra-deepwater penetration wells, and potentially long supply lines in remote areas require enormous equipment, from the supply boats to the MODU to helicopters. This amplifies the need for very capable stationkeeping systems on large vessels that must hoist and rotate extremely large loads. The potential to lose location, which is more a concern for DP than moored MODUs, requires emergency planning and rehearsals/drills to be prepared to prevent well control or vessel problems.

Another big difference between onshore and MODU operations is the number of people on the drilling unit. Depending on the operation, a MODU may have over 200 crew and personnel aboard. Besides the drilling crew, this includes marine crew and a host of specialists responsible for rig maintenance and operation. In addition, third-party service personnel stay aboard the vessel for long periods, because of the cost and difficulty of moving personnel to and from the rig. As a result, newer MODUs will have a very large accommodation facility, with over 250 bunks in predominantly 2-person rooms.

Most of the equipment on a MODU is very specialized and expensive, and crews must be trained to use it safely and efficiently. Operations are 24 hours a day, and planning ahead is one of the keys to a successfully drilled well. Teamwork and good communications are essential for the drilling crews, specialists, and marine personnel to have a smooth, safe, and efficient operation.

The remainder of this chapter will discuss the unique features of floating drilling equipment and floating drilling operations, with emphasis on special operations and emergency procedures. Obviously, many drilling operations are common to floating, bottom-founded and land drilling. This chapter and future updates will focus on special aspects of such operations for floaters. The IADC Drilling Manual, 12th edition, covers nearly all drilling operations, many of which are interesting and relevant to those specializing in floating operations. The print version of the IADC Drilling Manual includes all chapters. Please refer to www.IADC.org/ebookstore to peruse all IADC ebooks.

Environment and safety

While the mechanics of drilling a well are very similar for floating, bottom-founded and onshore operations, the potential safety and environmental consequences of an incident offshore, especially in deepwater, make a critical difference. Several environmental and safety risk considerations unique to floating operations are discussed in this section. While the risk-mitigation efforts identified in this section are also recommended for onshore drilling operations, the larger consequences of an incident over water has resulted in increased scrutiny and regulation of all floating drilling operations by industry, regulatory authorities, communities and other stakeholders.

In general, the consequences of an incident during floating

drilling operations include environmental damage from a spill that reaches the water or, in the event of any injury, delays in medical response and/or evacuation back to shore. The offshore response to environmental and safety incidents poses logistical challenges and requires supplemental resources not typically relevant to land drilling operations. These challenges translate into increased consequence and risk. (It's important to note that MODUs include an onboard medical clinic to conduct triage for major injuries and to treat minor injuries. Most offshore locations have a qualified emergency medical technician [EMT] on board at all times.)

Environmental impact assessment

Several proactive steps are typically taken to mitigate the increased risks of offshore operations. One of these proactive measures is an environmental impact assessment (EIA), a process for evaluating the likelihood that the environment may be impacted as a result of exposure to one or more environmental stressors, such as chemicals, oil, noise, or just the physical presence of a MODU in the water. One key environmental concern that every EIA will address is the possibility of a spill. The EIA will include spill trajectory modeling to simulate how and where a spill might spread in the water. Depending on the likelihood and severity of a consequence, the EIA might result in modifications to offshore operating procedures, such as avoiding operations during certain periods of time or increased environmental mitigation measures. When warranted, the EIA documentation will include an environmental mitigation plan.

All analyses in the EIA are compiled and submitted to regulatory authorities and shared with communities and other stakeholders to obtain permission for the floating operation to take place. Once approval to drill is granted, the mitigation measures identified in the EIA are implemented. These measures could include increased monitoring, operational delays, or detailed response planning. For example, if floating drilling operations are proposed in an area with endangered aquatic species or within the migration path of such species, certain restrictions to the drilling operation could be imposed, such as transport of drill cuttings to shore, rather than disposal at sea, or increased frequency of inspections for leaks or spills. The EIA will identify spill response resources that are required onboard the MODU should a spill occur; it may also require the staging of additional spill response resources close to shorelines to reduce spill-response time.

Shallow hazard assessment

Another proactive step typically taken to mitigate the increased risks of offshore operations is a shallow hazard assessment, which will examine the risks that might be imposed on the operation by sea floor conditions, as well as the geological formations in the shallow portions of the well. Sea floor risks include obstructions, such as marine organisms (e.g., tube worms) and subsea infrastructure (e.g., pipelines), and geographic issues, such as sea floor mountains and boulders. The geologic portion of the shallow hazard assessment will analyze the likelihood that the proposed wellbore will encounter shallow flows of water or gas.

Job safety analysis

Hazard assessments are also conducted for offshore safety concerns. Safety cases identify the hazards and risks of various operations, and then document how the risk is controlled and the safety management system in place to ensure the controls are effectively and consistently applied. Job safety analyses (JSA) are completed for all job tasks. A JSA is a risk-assessment process that helps integrate accepted safety and health principles and practices into all tasks necessary for an operation. The JSA is conducted before starting an operation, and identifies potential hazards for each step of the task, while recommending the safest way to do the job. A JSA is drafted or reviewed by those involved in completing the task. The goal is to ensure that actions designed to reduce risks as low as reasonably practicable (ALARP) are clearly understood and followed by the workforce to avoid an incident. Specialized or non-routine operations might employ further effort, such as a review of any potential dropped objects during an operation.

Simultaneous operations plans

Simultaneous operations plans (SIMOPs) are developed to consider additional risks that occur when two work activities are being done at the same time within close proximity to one another. Communication of SIMOPs risks and hazards during floating drilling operations is required. Well-defined communication protocols are followed to ensure everyone onboard the MODU is aware and alert.

Safety training and drills

Workers in an offshore environment require specialized training, not only for the technical aspects of the job, but also for the increased risks that exist there. This specialized training is closely monitored and tracked to ensure the physical capabilities of the workforce as well as their awareness of the additional environmental and safety risks in the offshore environment. Because medical treatment can be more difficult, given the remote nature of floating drilling operations, training and health education are also closely scrutinized to avoid incidents. As mentioned earlier, medical clinics with a certified EMT are standard aboard MODUs.

Safety plans and drills are conducted frequently offshore to ensure the workforce understands how to respond to emergencies and how and when to evacuate a MODU. Life-

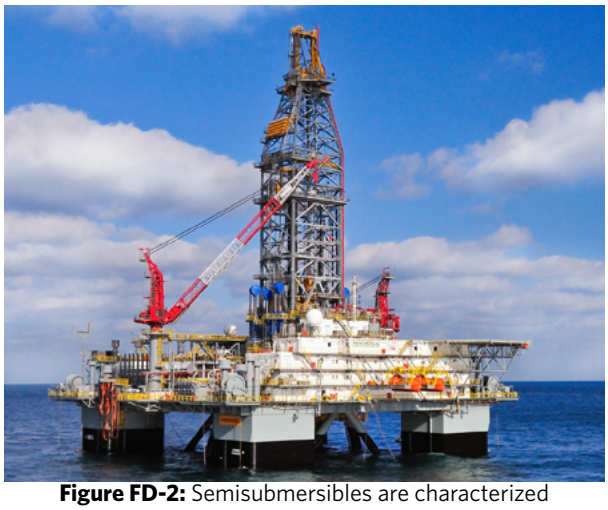

Figure FD-2: Semisubmersibles are characterized by an upper-hull structure supported on vertical columns connected to submerged lower hulls providing buoyancy for the rig. Courtesy Ensco plc.

boats are maintained to ensure personnel are able to escape should a significant incident occur.

Transportation logistics for floating drilling operations introduces other safety challenges. A variety of marine operations such as materials supply, rig towing, and rig mooring may be required, all of which have their own inherent risks. In addition, the workforce must be transported by boat or helicopter, both of which have safety requirements and regulations that must be followed, increasing the training required of an offshore workforce.

Conclusion

Despite the emphasis on safety and the environment, several catastrophic incidents have occurred in floating drilling operations. Analyses of incident lessons learned from these catastrophes have resulted in industry improvements in avoidance of incidents through detailed hazard analysis, increased understanding of risk potential, improved engineering and technology advancements as well as a more stringent requirements to operate. All of these efforts towards improved safety in floating drilling operations have significantly reduced the frequency of incident occurrences despite increased levels of such operations.

MODU floating equipment

Types of floating MODUs

Floating MODUs come in a variety of configurations, from simple drill barges to the most complex ultra-deepwater drillships. The common denominator for floating rigs is that they are all acted upon by the environmental forces of wind, wave, and offshore currents. Consequently, floaters require different equipment from that used in drilling a well from a stationary or bottom-founded unit. Each MODU type will react differently to a given environment and must compensate for the resulting vessel motions of heave, pitch, and roll. This requires unique equipment and procedures to carry out drilling operations safely and economically.

For example, the vessel must account for the constant change in vertical distance between the rig and the ocean floor caused by tides and heave. Various types of vertical motion compensation equipment are used to maintain a constant weight on the drill bit and to maintain the riser pipe connection between the rig and the BOP stack on the sea floor. As another example, vessel pitch and roll require special handling and securing of equipment to ensure that loads remain in control.

Floating MODU designs have evolved to minimize vessel motions, and the unique motion compensation equipment used on these vessels have evolved as well.

Semisubmersibles

Another type of offshore drilling vessel is the semisubmersible, characterized by an upper hull structure supported on vertical columns connected to submerged lower hulls providing buoyancy for the rig (**Figure FD-2**). The upper hull structure supports the rig's drilling equipment. While the most common semisubmersible configuration is a rectangular upper deck supported by two elongated pontoons, there are a number of other configurations currently in operation, such as triangular shapes with three submerged buoyancy pontoons and pentagonal vessels with five pontoons.

Pontoon shapes also vary across the industry. For example, some rigs have torpedo-shaped pontoons, while others have rectangular cross-sections. The size, number and configuration of semisubmersible support columns also vary as much as the configuration of the lower pontoons.

Until recently, stationkeeping for most semisubmersibles was based on an 8-point fixed-mooring system. Some moored semis equipped with self-propulsion use their thrusters for fixed-mooring assist (to relieve high loading on the leading mooring lines). Today, many of the newer semis have fully dynamically positioned stationkeeping systems.

Semisubmersibles generally have better weather operating envelopes than other types of floating MODUs. Semisubmersible rigs have superior motions characteristics, compared to ship-shaped or barge-shaped rigs, because their smaller water plane areas (the area of the columns supporting the upper deck structure) result in proportionally smaller vessel heave. Semisubmersibles with a fixed mooring configuration also experience less pitch and roll when the prevailing weather shifts than a ship or barge-shaped hull.

While semisubmersibles have superior motion character-

Figure FD-3: Drillships are self-propelled ship-shaped drilling vessels, with an opening in the middle (called a "moonpool") through which the drilling operation takes place. Courtesy Atwood Oceanics Inc.

istics, they generally have less deck-loading capability than other floating MODUs.

Drillships

Drillships are self-propelled ship-shaped drilling vessels, with an opening in the middle (called a "moonpool") through which the drilling operation takes place (**Figure FD-3**). Stationkeeping for early drillship configurations used traditional 8-point fixed mooring systems, which yield good longitudinal stability when the bow of the vessel is pointed into the prevailing weather, but poor stability when the weather shifts to the beam of the vessel. Moored drillships thus had high operational downtime due to vessel motions when the weather shifted away from the "optimal" direction. To overcome this operational limitation, all drillships built during the past 20-plus years utilize dynamic-positioning stationkeeping systems, which rotate the ship's bow into the changing weather and improve the rig's weather-related motions. Regardless of their stationkeeping system, drillships still have greater heave and roll motions for a given environment than a semisubmersible, because of their larger water plane area.

One significant advantage of drillships over semisubmersibles is their superior deck-loading capabilities. This higher deck-loading capacity, combined with self-propulsion, make drillships the vessel of choice for drilling remote offshore locations, where resupply of equipment and materials is difficult.

Ultra-deepwater drillships

As floating drilling moved into deeper waters, the size of the MODUs increased. Ultra-deep water depths (7,500 ft and beyond) and deeper overall well depths led to higher derrick and riser loads and the need for more storage and deck-load capacity. As a result, ultra-deep water MODUs now need a derrick capacity approaching 3 million lb, riser tensioning capacity of 4 million lb, and variable deck-load capacity in excess of 20,000 short tons. In nearly all cases, this combination of equipment and storage capacity dictates the use of a drillship-type configuration to carry these large loads. And, because of the impracticality of mooring in ultra-deepwater, these drillships are exclusively dynamically positioned to maintain station over the wellsite.

Besides larger vessels and equipment load capacities, other innovations that have further enabled ultra-deepwater drilling include a secondary load path to increase efficiency of running tubulars and equipment to the ocean floor, and multiple moonpools or false moonpools to decrease the vessel's water-plane area and reduce heave response.

Figure FD-4: Lattice boom cranes are a major deck crane aboard floating MODUs. Courtesy Noble Corp.

Figure FD-5: Pedestal-mounted knuckle boom cranes are important equipment aboard floating MODUs. Courtesy Noble Corp.

