ROTARY DRILLING

The Rotary Rig and Its Components

Fifth Edition

UNIT I • LESSON 1

ROTARY DRILLING SERIES

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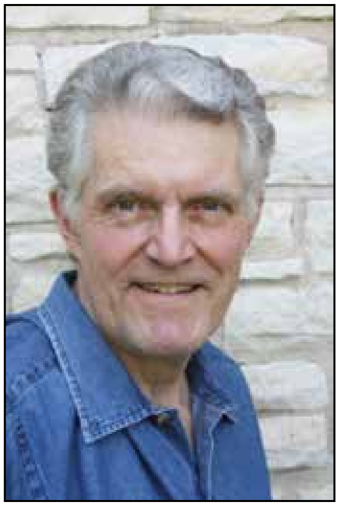

About the Author

After graduating from Texas Tech University, Mike Marcom started his oilfield career by roughnecking in West Texas. Later, he joined the North Sea Operations Group of Rowan Companies, Inc. At Rowan, he served in the Drilling Division in various capacities including those of Driller, Rig Superintendent, and Rig Manager; he then served as Managing Director of Rowan's European Operations and as Vice President of Rowan International, Ltd. When he retired as Operations Vice President in 2011, he had held responsibilities throughout the company for over thirty-five years. He currently provides industry-related consulting services.

Mike has been active in many organizations that advance the oil and gas industry. Those organizations include the International Association of Drilling Contractors (IADC), Society of Petroleum Engineers (SPE), American Association of Drilling Engineers (AADE), American Petroleum Institute (API), and Society of Naval Architects and Engineers (SNAME). In addition, he has served on the Executive Committee of the Gulf of Mexico Offshore Operators Committee (OOC), the Gulf of Mexico Area Maritime Security Committee (GOM AMSC), the Executive Committee of the API Committee on Standardization of Equipment and Materials (CSOEM), the National Offshore Safety Advisory Committee, and the API Drilling and Production Operating Standards Committee (DPOS). While active at Rowan, he represented the National Ocean Industries Association (NOIA) on the Oil and Natural Gas Sector Coordinating Council (ONG SCC), contributed to the oil and gas workgroup of the Homeland Security Information Network (HSIN), and chaired the IADC Jack Up Committee.

Units of Measurement

Throughout the world, two systems of measurement dominate: the English system and the metric system. Today, the United States is one of only a few countries that employ the English system.

The English system uses the pound as the unit of weight, the foot as the unit of length, and the gallon as the unit of capacity. In the English system, for example, 1 foot equals 12 inches, 1 yard equals 36 inches, and 1 mile equals 5,280 feet or 1,760 yards.

The metric system uses the gram as the unit of weight, the metre as the unit of length, and the litre as the unit of capacity. In the metric system, 1 metre equals 10 decimetres, 100 centimetres, or 1,000 millimetres. A kilometre equals 1,000 metres. The metric system, unlike the English system, uses a base of 10; thus, it is easy to convert from one unit to another. To convert from one unit to another in the English system, you must memorize or look up the values.

In the late 1970s, the Eleventh General Conference on Weights and Measures described and adopted the Système International (SI) d'Unités. Conference participants based the SI system on the metric system and designed it as an international standard of measurement.

The Rotary Drilling Series gives both English and SI units. And because the SI system employs the British spelling of many of the terms, the book follows those spelling rules as well. The unit of length, for example, is metre, not meter. (Note, however, that the unit of weight is gram, not gramme.)

To aid U.S. readers in making and understanding the conversion system, we include the table on the next page.

English-Units-to-SI-Units Conversion Factors

Quantity or Property	English Units	Multiply English Units By	To Obtain These SI Units
Length, depth, or height	inches (in.)	25.4	millimetres (mm)
		2.54	centimetres (cm)
	feet (ft)	0.3048	metres (m)
	yards (yd)	0.9144	metres (m)
	miles (mi)	1609.344	metres (m)
		1.61	kilometres (km)
Hole and pipe diameters, bit size	inches (in.)	25.4	millimetres (mm)
Drilling rate	feet per hour (ft/h)	0.3048	metres per hour (m/h)
Weight on bit	pounds (lb)	0.445	decanewtons (dN)
Nozzle size	32nds of an inch	0.8	millimetres (mm)
Volume	barrels (bbl)	0.159	cubic metres (m^3)
		159	litres (L)
	gallons per stroke (gal/stroke)	0.00379	cubic metres per stroke (m^3/stroke)
	ounces (oz)	29.57	millilitres (mL)
	cubic inches ($in.^3$)	16.387	cubic centimetres (cm^3)
	cubic feet (ft^3)	28.3169	litres (L)
		0.0283	cubic metres (m^3)
	quarts (qt)	0.9464	litres (L)
	gallons (gal)	3.7854	litres (L)
	gallons (gal)	0.00379	cubic metres (m^3)
	pounds per barrel (lb/bbl)	2.895	kilograms per cubic metre (kg/m^3)
	barrels per ton (bbl/tn)	0.175	cubic metres per tonne (m^3/t)
Pump output and flow rate	gallons per minute (gpm)	0.00379	cubic metres per minute (m^3/min)
	gallons per hour (gph)	0.00379	cubic metres per hour (m^3/h)
	barrels per stroke (bbl/stroke)	0.159	cubic metres per stroke (m^3/stroke)
	barrels per minute (bbl/min)	0.159	cubic metres per minute (m^3/min)
Pressure	pounds per square inch (psi)	6.895	kilopascals (kPa)
		0.006895	megapascals (MPa)
Temperature	degrees Fahrenheit (°F)	$\frac{°F - 32}{1.8}$	degrees Celsius (°C)
Mass (weight)	ounces (oz)	28.35	grams (g)
	pounds (lb)	453.59	grams (g)
		0.4536	kilograms (kg)
	tons (tn)	0.9072	tonnes (t)
	pounds per foot (lb/ft)	1.488	kilograms per metre (kg/m)
Mud weight	pounds per gallon (ppg)	119.82	kilograms per cubic metre (kg/m^3)
	pounds per cubic foot (lb/ft^3)	16.0	kilograms per cubic metre (kg/m^3)
Pressure gradient	pounds per square inch per foot (psi/ft)	22.621	kilopascals per metre (kPa/m)
Funnel viscosity	seconds per quart (s/qt)	1.057	seconds per litre (s/L)
Yield point	pounds per 100 square feet (lb/100 ft^2)	0.48	pascals (Pa)
Gel strength	pounds per 100 square feet (lb/100 ft^2)	0.48	pascals (Pa)
Filter cake thickness	32nds of an inch	0.8	millimetres (mm)
Power	horsepower (hp)	0.75	kilowatts (kW)
Area	square inches ($in.^2$)	6.45	square centimetres (cm^2)
	square feet (ft^2)	0.0929	square metres (m^2)
	square yards (yd^2)	0.8361	square metres (m^2)
	square miles (mi^2)	2.59	square kilometres (km^2)
	acre (ac)	0.40	hectare (ha)
Drilling line wear	ton-miles (tn•mi)	14.317	megajoules (MJ)
		1.459	tonne-kilometres (t•km)
Torque	foot-pounds (ft•lb)	1.3558	newton metres (N•m)

Introduction

In this chapter:

- The purpose of the rotary rig: drilling a well
- Portability of rotary rigs
- The functions of operators and drilling contractors
- Basics of the rotary drilling process

Oil and gas are normally found far below the surface, so special means of reaching them and bringing them to the surface must be used. Drilling through perhaps thousands of feet of earth, removing the dirt and rock from the hole as it is drilled, keeping the hole from caving in while it is being drilled, finding a particular layer of earth where oil or gas might be trapped, and providing a means of bringing it to the surface require considerable expertise, labor, and equipment. The primary equipment in this process is the *rotary drilling* rig and its components.

A rotary drilling rig, whether on land or offshore, can be thought of as a factory designed to produce only one product—an oilwell, or hole, as it is called in the business. This hole is a carefully planned path from the surface to a formation that might contain hydrocarbons. A rig differs from other manufacturing facilities, however, in that, once the hole is completed and the oil or gas is flowing to the surface, the rig is no longer needed to continue production. Once a well is drilled, the rig and its components can be disassembled, moved, and reassembled at a new location in order to begin drilling again.

The Power System

In this chapter:

- Power requirements of a rig
- Providing power to the components
- Transmitting power to the components
- Converting AC to DC
- Variability in the layout of a rig's power system

On nearly every rig, the power required for drilling the well comes from internal-combustion engines that are most often powered by diesel fuel. A rig needs from two to four or even more engines, depending on how deep the well is to be drilled. Big rigs typically have three or four 1,215-horsepower (906-kilowatt) engines with 1,200-kilovolt-ampere (kva) *generators* that together can generate 4,860 horsepower (3,624 kilowatts).

This horsepower or wattage is transmitted from the engines, or *prime movers* (the basic source of rig power), to the rig components through one of two types of drive—mechanical and electrical. On a *mechanical rig*, parts such as chains and pulleys transmit engine power to the components. Electric rigs sometimes require fewer of those types of parts and transmit electric power from the prime movers to electric motors at each component. Most new medium- to deep-capacity rigs are electric because they are easier to rig up and maintain than mechanical rigs are.

The power system uses the prime movers and the drives to produce and transmit power to the *hoisting*, *circulating*, and *rotating* systems. (The drilling systems are discussed in later sections of this book.)

For more information on power systems, see these titles from Unit I of the Rotary Series:

- Lesson 6: *The Drawworks and the Compound*
- Lesson 8: *Diesel Engines and Electric Power*

The Hoisting System

In this chapter:

- Raising and lowering the drill stem
- Supporting the suspended drill stem
- Moving the drill stem
- Supporting the drill stem and connecting it to the drawworks

During the drilling of a well, the hoisting system lifts the drill stem in and out of the hole. It also lowers the casing into the hole. The hoisting system consists of many pieces:

- The substructure
- The derrick or mast
- The drawworks
- The crown block
- The traveling block and hook
- The drilling line

For more information on the hoisting system, see these titles from Unit I of the Rotary Series:
- Lesson 5: *The Blocks and Drilling Line*
- Lesson 6: *The Drawworks and the Compound*

The Substructure

The *substructure* supports the derrick, the rotary table, and the full load of the drill stem when the stem is suspended in the hole or standing in the derrick. It also supports the casing string when the casing is being run in the hole. In addition, it raises the rig floor high enough to provide space under the rig for large valves called *blowout preventers* (discussed in a later section). The rig floor, which rests on top of the substructure, holds the drawworks, the driller's control panel, the *doghouse*, and other equipment.

The Rotating System

In this chapter:

- Rotating the drill string and bit
- Supporting the drill stem
- Circulating mud
- Cutting rock
- The telescopic shape of wellbores

The rotating system turns the drill string and the bit to drill a hole. The following pieces of rotating equipment make up the rotating system (from top to bottom):

- The swivel or top drive
- The kelly (if used)
- A saver sub
- The rotary table
- The drill pipe
- Tool joints
- Drill collars
- The bit

For more information on the rotating system, see these titles from Unit I of the Rotary Series:

- Lesson 2: *The Bit*
- Lesson 3: *Drill String and Drill Collars*
- Lesson 4: *Rotary, Kelly, Swivel, Tongs, and Top Drive*

The Circulating System

In this chapter:

- Cooling the bit, cleaning the hole, and balancing formation pressure in the well
- Moving the mud
- Mixing and storing the mud
- Cutting rock and circulating mud
- Types of drilling fluids

The circulating system circulates drilling fluid to the bit and back to the surface for cleaning and recirculation (fig. 41). For the rotary drilling system to function, fluid must be circulated downward through the drill stem, around the bit, and upward in the *annular space* between the drill stem and the wall of the hole or the casing (fig. 42). A circulating system uses the following components to circulate, clean, and recirculate drilling fluid:

- Mud pumps
- The rotary hose
- The swivel or top drive
- The drill stem
- The bit
- The mud return line
- Mud tanks
- Compressors, if the circulating system uses air or gas

For more information on the circulating system, see the Rotary Series, Unit I, Lesson 7: *Drilling Fluids, Mud Pumps, and Conditioning Equipment.*

Well-Control Equipment

In this chapter:

- Preventing blowouts
- Detecting a kick and bringing it under control
- Closing in the well
- Powering the blowout preventers
- Applying back-pressure to the drilling column
- Treating mud from a kick

A blowout is an uncontrolled flow of gas, oil, or other well fluids into the atmosphere or into an underground formation. It can occur when formation pressure exceeds the pressure applied to it by the column of drilling fluid. A blowout endangers the lives of the crew and wastes petroleum; it can also damage the environment and destroy a rig worth millions of dollars. Although relatively rare, a blowout is an awesome sight. Fluid (oil, gas, or salt water) erupts from the well with great force and often ignites into a roaring inferno, especially if it contains gas (fig. 50). The crew uses *well-control equipment* to prevent blowouts.

A blowout is a dangerous situation. A kick, or a sign that conditions are leading to a blowout, can be detected by the crew.

Another way the crew prevents these events is by using the right amount of drilling mud of the proper density. Even when the right mud "recipe" is used, however, if the bit drills into a formation with higher-than-expected pressure or if the crew allows the mud level in the hole to drop, the well can *kick*. During a kick, formation fluid enters the hole and forces some of the drilling mud out.

Auxiliary Equipment

In this chapter:

- Powering the auxiliaries
- Treating used mud
- Monitoring drilling parameters
- Storage facilities, crew accommodations, and telecommunications systems

In addition to the major pieces of equipment that make up a drilling rig, many relatively minor pieces of equipment are necessary. The main systems—for power, hoisting, rotating, circulating, and well-control—all have support equipment that makes it possible for the rig to function. How the rig will be used influences both the number and types of *auxiliaries* chosen for operations. Variables such as terrain, climate, remoteness from supply centers, and transportation requirements also have an influence on the choice of auxiliaries.

In the offshore environment, drillships and *mobile offshore drilling units* (*MODUs*) capable of floating have the drilling rig and auxiliaries so firmly integrated into the structure and function of the unit that it is often difficult to differentiate between the equipment required for drilling operations and the equipment required to operate the unit. For example, the prime movers might be used to generate power for both drilling and operating functions. For this reason, it is normal to refer to one of these purpose-built whole units as a "rig," even though the rig is technically only constituted of the drilling equipment mounted on the unit.

For more information on auxiliary equipment, see the Rotary Series, Unit I, Lesson 9: *The Auxiliaries.*

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