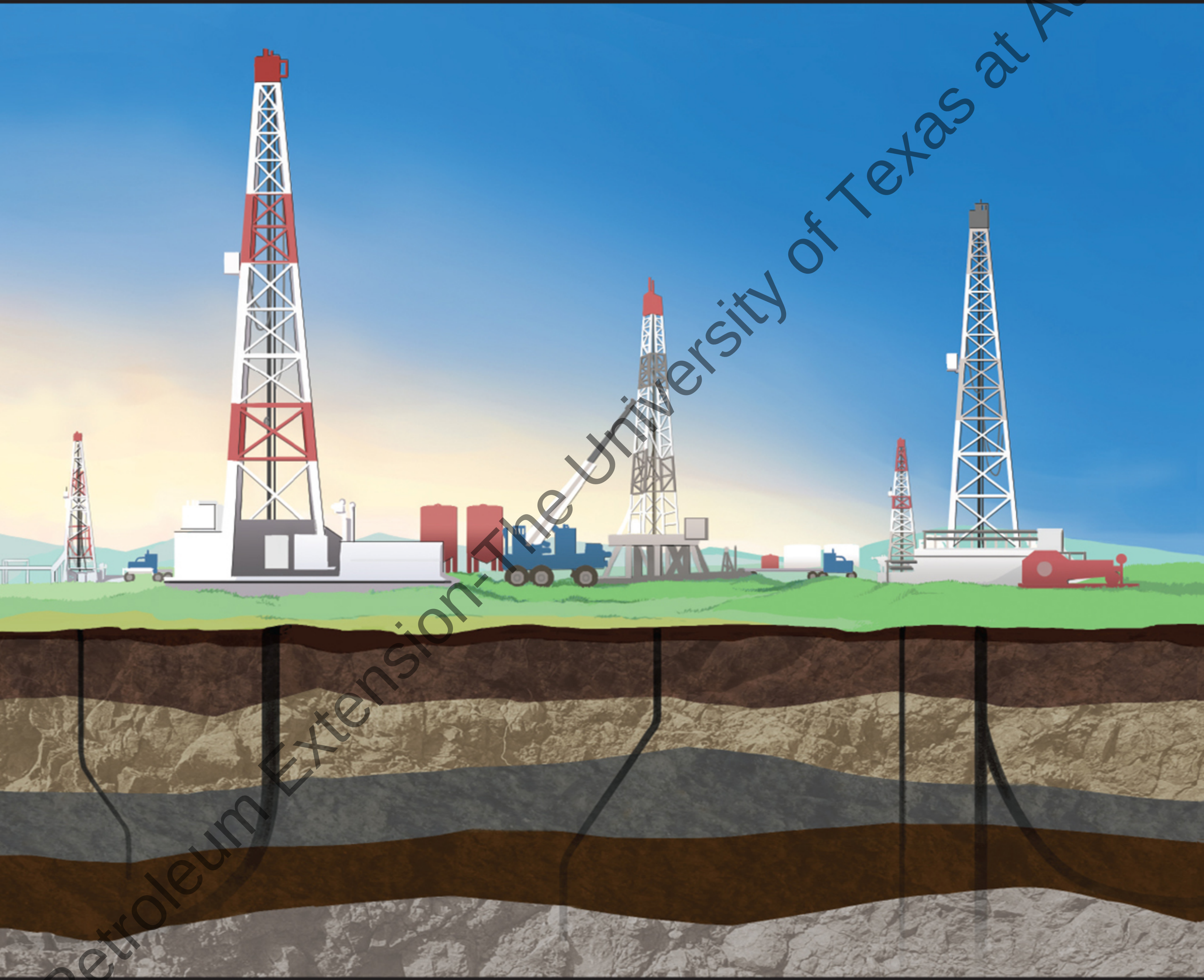
DRILLING TECHNOLOGY

SEGMENT

1 Introduction to Rotary Drilling



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About the Author

Dr. Robello Samuel is a Halliburton Technology Fellow working with Halliburton since 1998. He is currently a research and engineering lead for well engineering applications and responsible for research and scientific activities for new drilling technologies. He has more than twenty-five years of multidisciplinary experience in domestic and international oil/gas drilling and completion operations, management, consulting, software development, and teaching. His skills include practical and theoretical background in onshore and offshore well engineering, cost estimates, supervision of drilling operations, personnel, and technical review as well as creative establishment of project relationships through partnering and innovation. Concurrently, he has been an adjunct professor at the University of Houston and Texas Tech University in Lubbock for the past 10 years.

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Dr. Samuel, an SPE Distinguished Lecturer, holds B.S. and M.S. (mechanical engineering) degrees from The University of Madurai and College of Engineering, Guindy, and M.S. and Ph.D. (petroleum engineering) degrees from Tulsa University. Samuel's unique blend of skills as a field engineer, researcher, and instructor has helped him author seven drilling books and a forthcoming book *Drilling Engineering Optimization*.

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 Systeme International (SI) d'Unites. Conference participants based the SI system on the metric system and designed it as an international standard of measurement.

The Drilling Technology 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)

1 LESSON

Subsurface Geology

In this lesson:

- Petroleum geology
- Geological structures
- Application of geological concepts
- Petroleum reservoirs
- Early rotary drilling

Thousands of years have passed since humans first scratched the surface of Earth in search of food, water, and a supply of energy. Oilwells are now being drilled to depths of almost eight miles (13 kilometres) in the continuing search for the lifeblood of the modern world—fossil fuels. The first oilwell in the United States was a 69-foot (21-metre) hole drilled by Edwin Drake in Pennsylvania in 1859. Several thousand wells have since been drilled offshore, and drilling has been achieved in over 10,000 feet (3,048 metres) of water. The quest to drill in ultra-deep water to reach depths of more than 40,000 feet (12,192 metres) is underway and within reach. Rotary drilling rig power has increased from 1 horsepower (hp) 100 years ago to more than 10,000 hp in the equipment now used offshore.

To understand the basic principles of rotary drilling, one must first understand the basic principles of geology, because most petroleum is found in the Earth's underground formations made of rock.

Petroleum Geology

Geology is the science of the Earth and the processes of its change that have taken place over vast time, especially as recorded in rocks. Because petroleum is an accumulation of past life buried beneath thousands of feet of rock, geological studies play an important part in finding oil and gas.

2 LESSON

Rotary Drilling Rigs

In this lesson:

- The basics of rotary drilling
- The structure of rigs
- Powering the rig
- Rig components and systems
- Blowout preventers and auxiliaries
- Rig design considerations

Early Rotary Drilling

The first rotary drilling rig was developed in France in the 1860s for the mining industry. Variations of the rig appeared in the United States. It was unpopular at first, because drilling companies mistakenly believed that most petroleum lay in hard rock formations and therefore thought they could drill effectively using cable-tool rigs. In the 1880s, two brothers named M.C. and C.E. Baker drilled successful water wells in soft formations of the Great Plains of the United States with a rotary unit and fluid-circulating system. The rotary technique proved equally successful in the soft rocks of the Corsicana oilfield in Texas, which was accidentally discovered by drillers searching for water. When Anthony Lucas finally succeeded in drilling the Lucas well in the Spindletop oilfield in Texas using rotary drilling, the method spread rapidly in the developing industry (fig. 18). Before long, oilwells were springing up in great numbers using rotary drilling methods (fig. 19).

3 LESSON

Circulating Equipment

In this lesson:

- The fluid circulation system
- Mud conditioning and accessory equipment
- Storing and handling mud
- Mud cleaning equipment
- Types of mud pumps

The main components of the fluid circulation system are the pump, hose and swivel, drill string, bit, mud return line, and the pits (fig. 40). Mud conditioning equipment includes shale shakers, mud agitators, desanders, desilters, mud centrifuges, mud-gas separators, and degassers. Accessory equipment to the mud circulation system includes the standpipe, chemical tank, mixing hopper, mud storage facilities, and mud pit instrumentation. Drilling fluid can be divided into two broad categories—liquid and gas.

4 LESSON

The Drill Stem

In this lesson:

- Design and characteristics of drill pipe
- Tool joints and drill collars
- Drill stem auxiliaries
- Operations involving the drill stem

The *drill stem* includes all items used for rotary drilling from the swivel to the bit. This comprises the kelly, drill pipe, tool joints, drill collars, stabilizers, and miscellaneous other pieces of equipment such as drill-stem subs, reamers, stabilizers, and shock subs. The *drill string* is composed only of the drill pipe with attached tool joints. It is used to transmit the rotation of the rotary table or top drive and serve as a conduit for circulation of the drilling fluid. (Although by definition, the kelly is a part of the drill stem, it is not discussed in this lesson.)

During the early days of rotary drilling, components such as pipe, couplings, and drill collars by any given manufacturer often would not match similar products made by another manufacturer. Wall thicknesses differed, so inside and outside diameters of items used in the drill stem varied considerably. Additionally, the threads would not always mate. This confusion led the American Petroleum Institute (API) to standardize threads and fittings. Specifications were also made for the types of material to be used, the methods of manufacturing, and the dimensions of pipe, threads, and mating connections.

5 LESSON

The Bit

In this lesson:

- How bits drill boreholes
- Bit types, selection, and performance
- Components of roller cone and diamond bits
- How to prevent untimely wear
- Calculating operation costs

The bit is the primary cutting, or boring, element used to drill for oil and gas. It is made up and positioned on the bottom-most portion of the drill stem where it is in contact with underground rock. The bit is designed to rotate along with the other components that make up the drill stem. As it does so, its cutting elements—which can include steel teeth, tungsten carbide inserts, or diamonds—cut and dislodge the layers of rock. As the rock is cut, drilling fluid traveling down the drill string is released out of the bit to displace the fragmented rock (fig. 91).

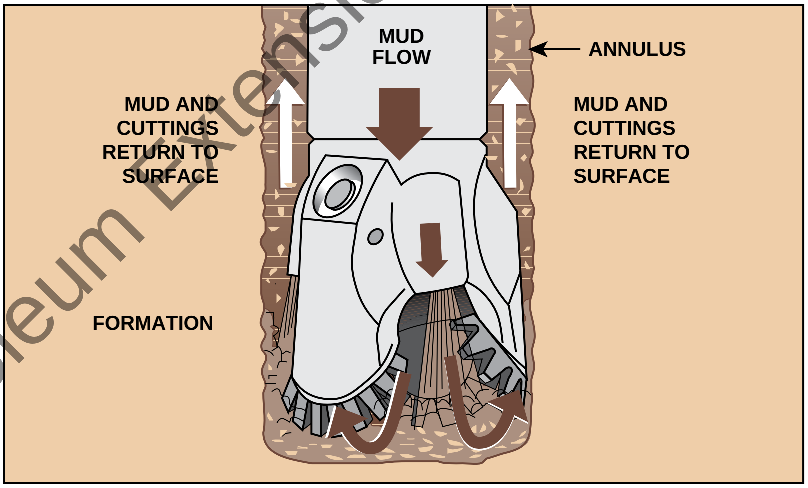

Figure 91. A bit drilling the bottom of a hole. The drilling mud is released from the bit to carry cuttings to the surface.

Conclusion

The five lessons in this segment of the Drilling Technology Series teach the background necessary for someone embarking on a career in drilling technology. From the basics of petroleum geology to the specifics of a drilling rig and its components, this text covers important aspects of the rotary drilling process such as the circulating system, the drill stem, and the bit. With the completion of all five lessons, readers have gained important knowledge of the major components of drilling. To reinforce learning, an optional online assessment designed as an open-book test is available to go along with this book (can be purchased as a bundle with the book or as a separate tool).

For further understanding of the topic of rotary drilling, the next step is to take an in-depth look at routine drilling operations. Segment II provides the fundamentals of such operations for readers eager to receive practical procedural instruction. As a whole, the Drilling Technology Series collects a wealth of material about all phases of drilling and assembles it into four distinct manuals (segments). Although primarily designed for industry personnel and college students studying petroleum technology, the information is extremely useful for anyone who wants or needs to know more about rotary drilling.

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