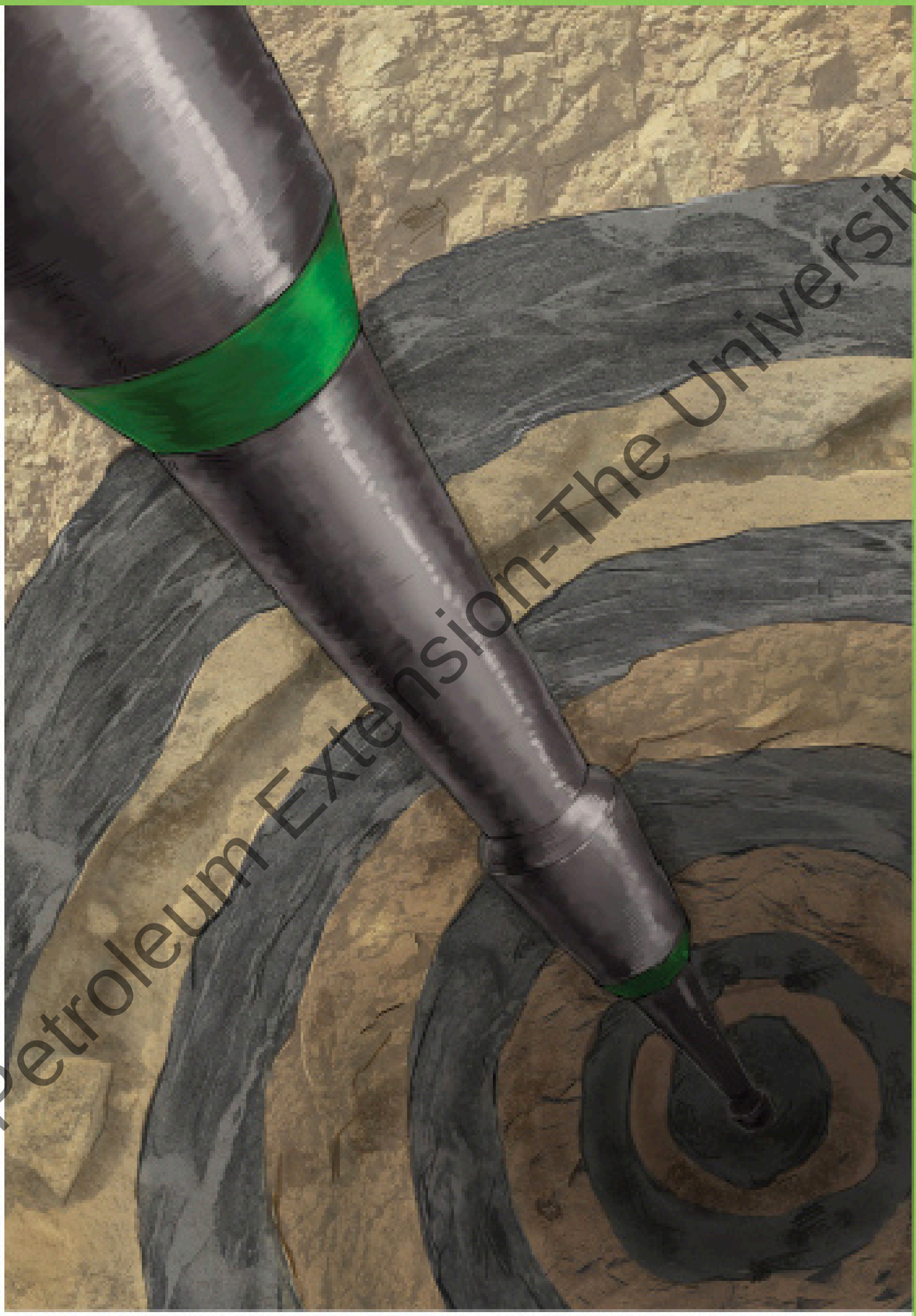
ROTARY DRILLING

Drlling a Straight Hole



Fourth Edition

UNIT II • LESSON 3

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ROTARY DRILLING SERIES

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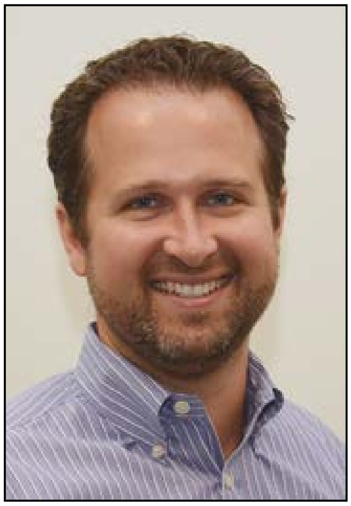

About the Author

Ben Randell graduated from the University of Adelaide, South Australia, with a double engineering degree in Petroleum and Chemical Engineering. He completed two honors theses in industry, investigating compressor optimization in a central Australian gas basin and the reservoir souring of an offshore Australian gas field. He began with Chevron Canada as a drilling engineer in 2006 where he was involved in appraising Chevron's northern Alberta heavy oil asset. In 2008, he worked as a drill site manager in San Joaquin Valley, central California, supervising drilling operations in Chevron's fields across the region. Two years later, he became the drilling engineer responsible for planning and overseeing execution of Chevron's wells in the TTA asset, central California.

He also served as the regional subject-matter expert for directional drilling, providing technical guidance and issue resolution to Chevron engineers and external service companies. In 2012, Randell joined Chevron's global Energy Technology Company in Texas and led the Decision Support Center, providing real-time engineering and operational support to Chevron's most complex global operations.

Randell has been involved with a variety of well designs from simple, shallow vertical wells to aggressive horizontals using tools ranging from single-shot surveys to gyroscopic technology.

Over the years, he has undertaken extensive technical training on diverse topics such as directional drilling. He is grateful for these experiences and acknowledges the instructors of these courses for imparting the knowledge required for this textbook. He also wishes to thank all of the mentors throughout his career, who all indirectly helped to shape this book.

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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.

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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)

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Introduction

In this chapter:

- Problems of crooked holes
- Early wellbore survey tools
- Contract deviation clauses
- Directional equipment for vertical holes

When rotary drilling first began, operators and drillers assumed that if they held the kelly vertical when starting the hole, the drill string and bit would drill a straight hole. During the two-year Seminole boom in Oklahoma that began in 1928, the industry began to suspect that this hypothesis was not true. On occasion, *wellbores* actually intersected. In addition, actual drilled depths did not correspond to projected *formation* depths. Obviously, the Oklahoma *rigs* were drilling holes that deviated from vertical.

These *crooked holes* were not just a problem for geologists. For drilling personnel, a crooked hole required more footage compared to a straight hole (fig. 1). Consequently, the operator had to pay for the extra footage or extra rig time, depending on the type of *drilling contract*. Furthermore, contractors occasionally drilled into existing boreholes or producing wells on *offset leases*, creating serious health, environment, safety, and legal problems. Hole *deviation* became such an important consideration that operators began looking for ways to determine the amount of *downhole* deviation needed.

Crooked holes cost more to drill and pose a risk of intersecting other wells underground.

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Straight Hole Considerations

In this chapter:

- Definition of a straight hole
- Restricting the total hole angle
- About doglegs and keyseats
- Dogleg and keyseat problems

The term *straight hole* generally defines a borehole that a drilling contractor has drilled vertically from surface to *Total Depth* (TD). A straight hole does not have to be vertical but must not contain significant curvature or angle changes. This means that most straight holes will be vertical, unless they are drilled with a slant rig. However, it is virtually impossible to drill a perfectly straight hole. Therefore, all wellbores will deviate from vertical to some extent. Vertical drilling contracts recognize this fact and allow a variation from the strict specification. Therefore, straight hole drilling is best categorized as controlled deviation drilling, where the industry accepts a straight hole as one that meets two qualifications:

- The hole stays within the boundary of a cone, as designated by the operator in the deviation clause of the contract. The total hole angle is therefore restricted (fig. 10).
- The hole does not change direction rapidly, usually no more than 3 degrees per 100 feet (30 metres) of hole. The rate of hole-angle change is therefore restricted.

Staying within these allowable parameters, the contractor's main objective is to deliver a straight and usable hole to the specified depth.

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Factors Affecting Hole Deviation

In this chapter:

- Deviation from vertical
- Formation effects
- Variation in formation drillability
- Mechanical effects
- Bit selection

There are two factors that can cause a hole to deviate from the vertical—the formation being drilled and the equipment used to drill. Both of these conditions have specific effects on hole deviation.

Formation Effects

The type of formation being drilled affects hole deviation. Two formation characteristics that affect the bit's ability to drill a straight hole are *formation dip* and variation in the drillability of formations. In most cases, these characteristics are unknown and unwanted because they cause the bit to deviate from vertical, or *walk*. However, in developed oilfields, the walking behavior of the bit can be incorporated into the well design and the surface location appropriately shifted so the bit deflects and drills to the desired bottomhole location.

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Methods of Controlling Hole Deviation

In this chapter:

- Vertical starts
- Using the right bottomhole assembly
- Types of assemblies and designs
- Drilling parameters

Although crewmembers can sometimes correct a crooked hole, the operation is often expensive. They might have to plug back and re-drill a crooked portion of the hole to straighten it. Or, in extreme cases, they might have to *skid the rig* and start a new hole. The best approach to use when drilling in crooked-hole country is to employ preventive measures, such as:

- Drilling a shallow and vertical surface hole
- Obtaining an accurate geological prognosis
- Selecting the best drilling method for the area; for example, standard rotary, air rotary, air percussion, or downhole mud motor
- Using tools to monitor the well deviation while drilling; for example, MWD
- Using the optimum BHA, or switching out BHAs, as required while drilling
- Reducing WOB and maximizing ROP as much as practical

When planning wells, it is important to consult bit records, *deviation surveys*, drilling time charts, *daily drilling reports* (fig. 28), geological prognoses, and any other available information from nearby wells.

Plan the hole trajectory to avoid the costly and time-consuming correction of a crooked hole.

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Drill Stem Tools

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In this chapter:

- Standard drill collars
- Square and spiral drill collars
- Stabilizers
- Vibration dampeners
- Measurement-while-drilling tools

Operators use several *drill stem* tools to control deviation and drill straight holes. Such tools include: standard drill collars; heavy-walled and heavyweight drill pipe; square drill collars; spiral drill collars; stabilizers; vibration dampeners; and measurement-while-drilling (MWD) tools.

Standard Drill Collars

Today, operators use long strings of drill collars virtually everywhere, even in soft formations (fig. 48). Drill collars supply weight to the bit for drilling and maintain weight to keep the drill string above from bending or buckling under its own weight (fig. 49). Drill collars also prevent high doglegs by adding stiffness to the BHA and by supporting and stabilizing the bit.

Drill Collar Size and Weight

Most collars are between 30 and 31 feet (9.14 to 9.45 metres) long; their weight varies considerably depending on the OD and ID (*bore*) of the drill collar. For example, one of the lightest collars has an OD of 3 inches (76.2 millimetres) and weighs 640 pounds (290.3 kilograms).

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Deviation-Recording Instruments

In this chapter:

- Measuring drift
- Measuring direction and angle
- How the go-devil works
- Running methods
- Types and usage of instruments

Depending on the type of drilling contract between the contractor and the operating company, it might specify the maximum deviation a drilling contractor is allowed. The contract may also state how often a deviation survey is to be run. This frequency can vary in terms of footage (or metreage) drilled, from 15 to 500 feet (5 to 170 metres), depending on the area to be drilled (see fig. 8). Intervals of 100 to 250 feet (30 to 75 metres) are normal in areas where drilling is slow and few deviation problems occur. If deviation problems are expected, contractors might be required to run a survey more often or, for their own protection, they might decide to run a survey more often. Frequent surveys are desirable but they can also be risky, time-consuming, and expensive. Many contractors own deviation-recording instruments, but the cost in downtime required to lower and retrieve the instruments can become excessive if too many surveys are run. Furthermore, whenever a survey is run, there is a risk of sticking the drill string or causing problems with the deviation tool.

Go-devil = device in which the survey instrument is run.

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