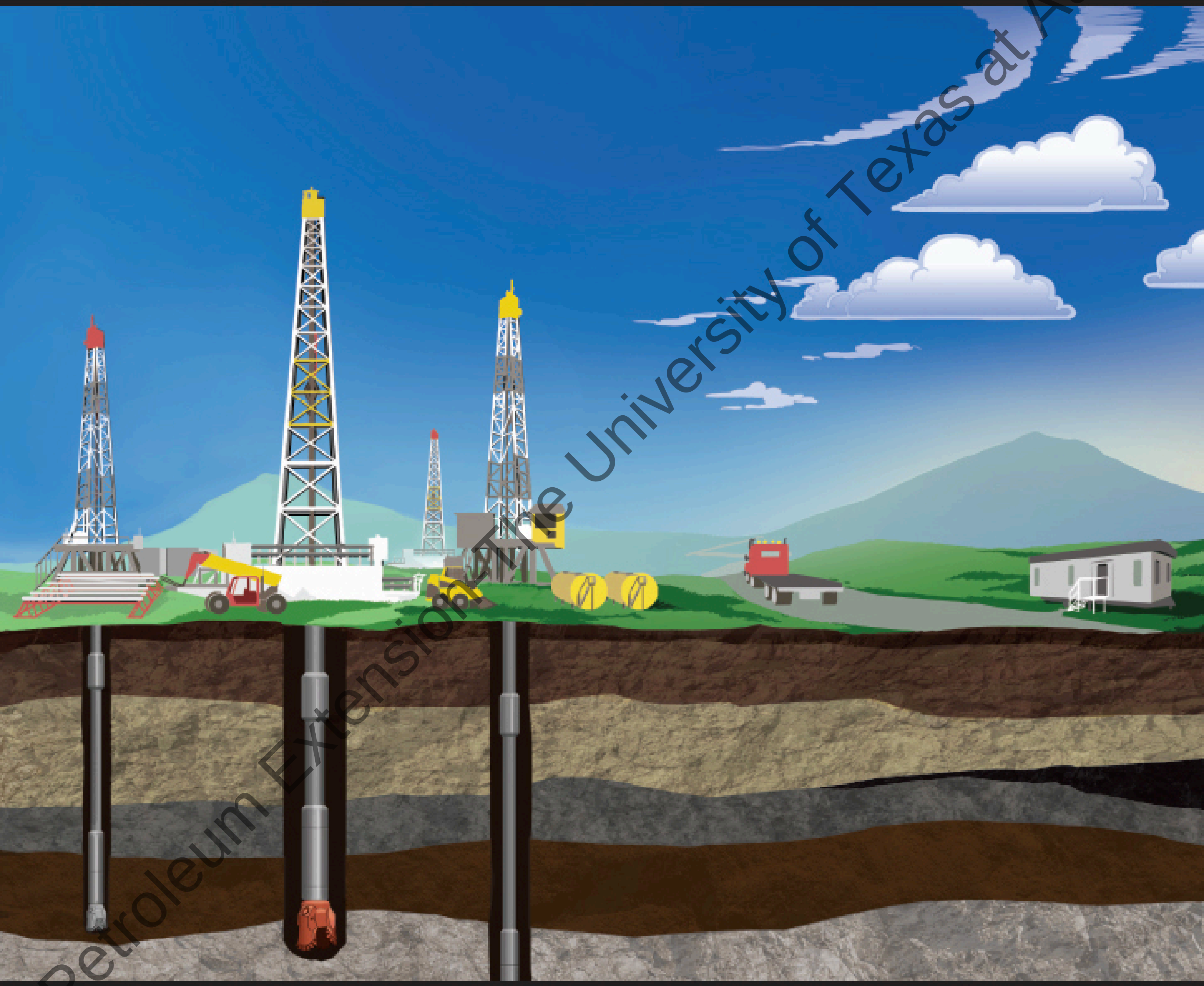
DRILLING TECHNOLOGY

SEGMENT

2 Routine Drilling Operations



The University of Texas at Austin • Petroleum Extension Service

Contents

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

Drilling a Straight Hole

In this lesson:

- Hole-angle change
- Causes of hole deviation
- Controlling hole deviation
- Bottomhole assembly tools
- Straight-hole survey instruments

Prior to about 1930 and the development of deviation-recording instruments, crooked holes were not considered a problem for *rotary drilling*. It was believed that if a hole was started vertically, it would remain straight during drilling from top to bottom. Wells tended to be shallow, and not many were drilled below 5,000 feet (1,524 metres). Penetration was slow because *weight on bit* (*WOB*) usually did not exceed 15,000 pounds (6,675 decanewtons or daN). *Drill collars*, as we know them today, were not used. Instead, the *bottomhole assembly* (*BHA*) usually consisted of a fishtail bit, a crossover sub (called a collar), and *drill pipe*. A portion of the drill pipe was run in compression in order to supply the desired WOB.

No one suspected that wells were crooked until about 1928 during the Seminole boom in Oklahoma. During the development of the Seminole field, it was realized that some wells required considerably more *casing* to complete than others, even though the wells were supposed to be in the same *producing horizon*. The existence of crooked *wellbores* was finally recognized when a well drilled by one contractor intersected another wellbore. Because operators had to pay for the extra footage drilled and purchase extra casing, tubing, and rods if the well had to be pumped, *deviation* became a concern.

2 LESSON

Rig Hydraulics

In this lesson:

- The hydraulic system
- Pressure losses in the system
- Bit hydraulics
- Annular hydraulics
- Designing the rig hydraulics program

Hydraulic, or fluid, horsepower is a significant factor in nearly all phases of rotary drilling. In drilling, particular emphasis is placed on *hydraulic horsepower* (*hhp*)—the amount of energy delivered to circulate fluid. At the drilling face, the energy of the drilling fluid is used as a powerful jet stream to sweep cuttings out of the way of the oncoming bit. Consequently, hhp at the bit is critical to drilling performance because it determines how much work the drilling mud can do. Without an adequate supply of hhp at the bit, high penetration rates are not possible. WOB, rotary speed, and hhp are interrelated. Typically, a substantial amount of hole is drilled when a high amount of hydraulic energy passes through the bit jets, a relatively heavy weight is placed on the bit, and a high rotary speed is applied. By contrast, if the hydraulic, or circulating, system does not deliver enough power to the bit to remove the cuttings rapidly, increasing the bit weight and rotary speed will not increase the ROP.

The main requirement of the *circulating system* is to provide sufficient hhp to the bit to clean the bottom of the hole. After performing its work on bottom, the mud must also have enough power to carry drilled cuttings, including any particles that enter the mud stream from other parts of the wellbore, to the surface and maintain the walls of the hole. This is extremely important in troublesome formations, such as sloughing shales. An inefficient *hydraulics* program will result in poor penetration rates and can lead to other problems, such as stuck pipe, hole bridging, or fill-up on bottom after trips.

3 LESSON

Drilling Fluids

In this lesson:

- Functions of drilling fluid
- Water-base muds and oil muds
- Pneumatic fluids
- Drilling fluid composition and properties
- Field testing drilling fluids

The ancient Chinese, who made use of the spring-pole drilling technique in the 5th century, were among the first to use water to soften rock and remove cuttings. However, the importance of drilling fluid was not clearly demonstrated until rotary drilling surpassed the hammering and percussion technique of *cable-tool drilling* in the 1900s. In fact, the continuous circulation of drilling fluid is the primary reason why the rotary drilling method became so successful.

Drilling fluid is circulated through a wellbore so the cuttings that the bit produces at the bottom of the hole can be carried to the surface. Drilling fluids that are liquid are commonly referred to as drilling mud or simply, mud (fig. 65) However, not all drilling fluids are liquid. Air, gas, and gaseous mixtures, such as *foam* and *aerated drilling muds*, are used in some drilling operations. The type of drilling fluid selected for a well depends on the formations that will be drilled and the complexity of the well design. For example, when very deep and consequently hazardous wells are drilled, the drilling fluid is required to have the correct physical and chemical properties to withstand a variety of well conditions. The fluid that will offer the lowest overall drilling cost and minimize potential problems is usually selected based on local experience. The cost of maintaining the right properties, however, can be high and is often considered a major drilling expense.

4 LESSON

Casing

In this lesson:

- Types of casing used on land and offshore
- Casing standards and specifications
- Casing string design, strengths, and sizes
- Types of casing accessories
- How to prepare and set casing

Drilling for oil and gas involves boring a hole to the petroleum accumulation and installing pipe from the reservoir to the surface. The pipe, which extends from the target zone to the surface, is called casing (fig. 84). It acts as a protective lining in the wellbore. Casing is large-diameter steel pipe that is usually cemented into the hole to ensure a pressure-tight connection to the oil or gas reservoir. Running casing into the hole is very similar to running drill pipe except that the

Figure 84. Casing stacked for use in a drilling operation

5 LESSON

Cementing

In this lesson:

- Mixing and pumping cement
- Cement volume requirements
- Considerations after cementing
- Oilwell cements and additives
- Secondary cementing

Oilwell cementing is the process of mixing and placing cement slurry in the *annular space* between a string of casing and the open hole. The cement sets, bonding the pipe to the formation. A good cement job affects how much a well can produce over the course of its life. Poor cementing operations can result in a failure to isolate the subsurface zones or cause corrosion failures in production equipment. Because the effectiveness of a cementing operation can be affected by many factors—such as contaminated or incorrect amounts of water, use of improper cement, hole enlargement, and mud channels—careful planning is necessary. Cementing procedures can be classified into primary and secondary phases:

- *Primary cementing* is performed immediately after the casing is run into the hole. It serves to restrict fluid movement between formations and the surface, provide support for the casing, prevent pollution of freshwater formations, and prevent casing corrosion.
- *Secondary cementing* includes plug-back to another producing zone, plugging a dry hole, and formation squeeze cementing. Although these secondary cementing jobs are performed as a part of *well servicing* and *workover*, they are discussed briefly at the end of this lesson.

Conclusion

The five lessons in this segment of the Drilling Technology Series teach the background necessary for someone embarking on a career in rotary drilling. This text examines important aspects of routine drilling operations, beginning with an exploration of best practices, surface equipment, BHAs, bit and annular hydraulics, drilling fluids, casing runs, and cementing operations. Upon completing all five lessons, readers will have gained important knowledge of the major facets of drilling. To reinforce learning, an optional online assessment designed as an open-book test is available for purchase with this book. Completion of the test after reading the book provides the opportunity to receive a Completion Certificate and earn valuable Continuing Education Units (CEUs).

To further your understanding of rotary drilling, the next step is an in-depth look at special drilling operations, including controlled directional drilling, open-hole fishing, and blowout prevention. Segment III, *Special Drilling Operations*, provides the fundamentals of such operations for readers who are eager to receive practical procedural instruction. Also consider adding Segment I, *Introduction to Rotary Drilling*, to your personal library to learn about petroleum geology, the rotary drilling process, and key downhole tools, such as the bit. Segment IV, which is currently in development, explores critical aspects of offshore operations.

As a whole, the Drilling Technology Series includes a wealth of information about all phases of drilling. No other program in today's marketplace offers the same breadth of material in one location as this unique, easy-to-use collection. Although primarily designed for industry personnel or college students studying petroleum technology, it is useful for anyone who wants or needs to know more about rotary drilling.

Index

Througout this index, *f* indicates a figure and *t* indicates a table on that page.

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