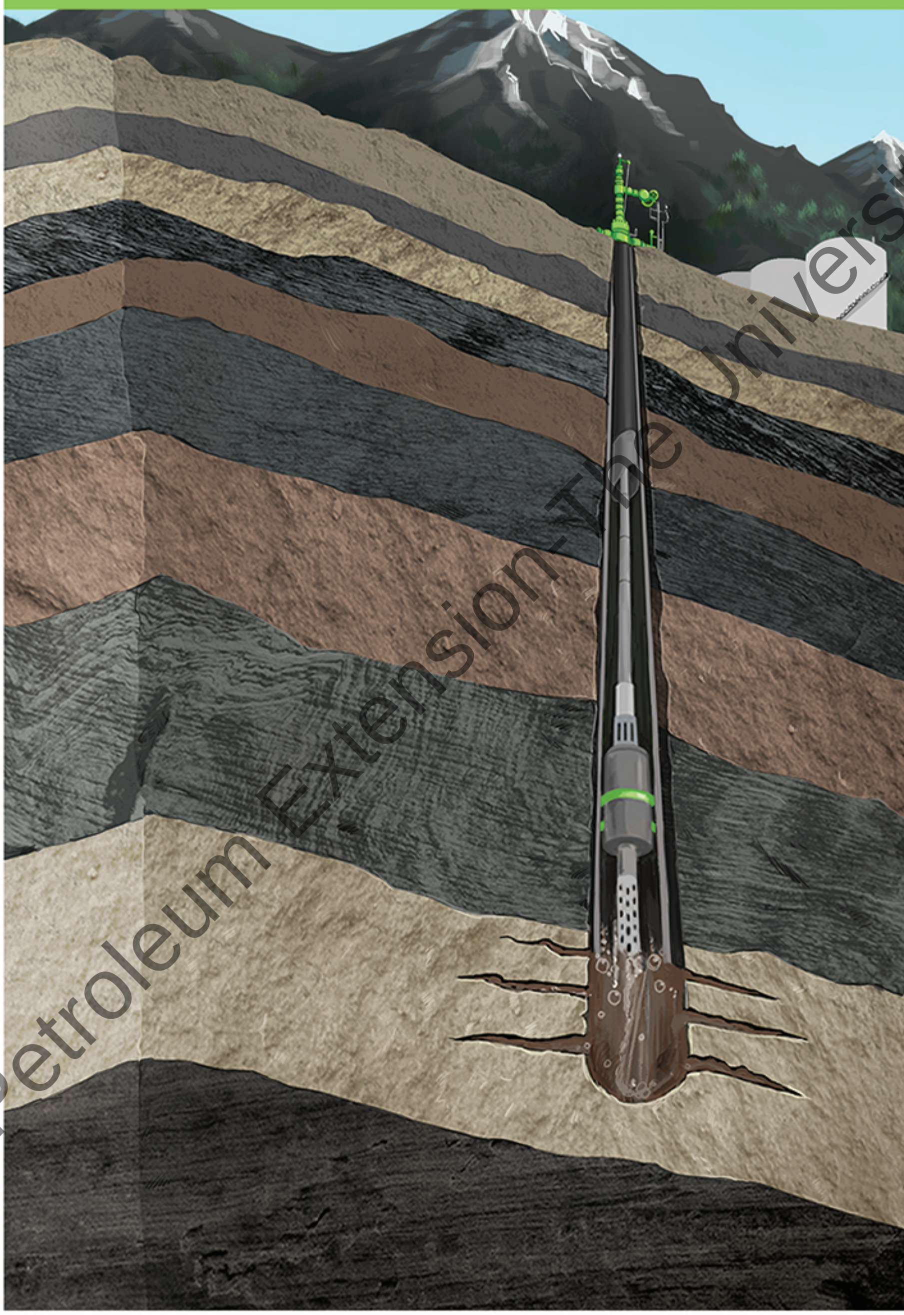
ROTARY DRILLING

Testing and Completing



Third Edition, Rev.

UNIT II • LESSON 5

ROTARY DRILLING SERIES

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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.

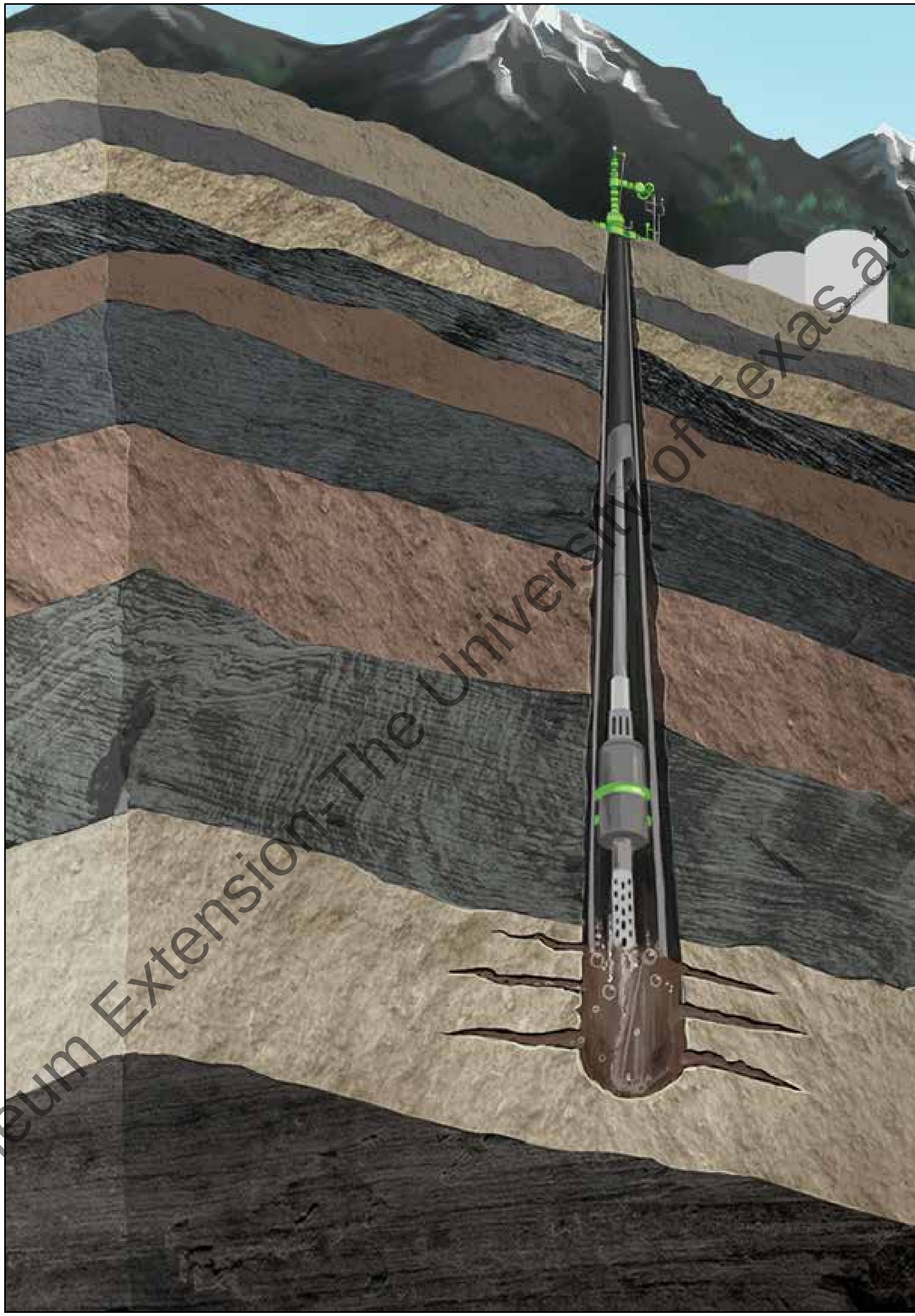
In the late 1970s, the Eleventh General Conference on Weights and Measures described and adopted the Systeme International (SI) d'Unités. Conference participants based the SI system on the metric system and designed it as an international standard of measurement.

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:

- Factors affecting fluid production
- Reservoir rock formations
- Porosity and permeability
- Reservoir characteristics

To improve recovery of petroleum and reduce costs, a well completion must be planned carefully using data from testing.

Well completion methods vary a great deal because not only are no two wells exactly alike, but also no two producing companies handle a well the same way. It is impossible to talk about the typical well completion because it does not exist. Personal preferences and experience dictate the choices made in selecting individual steps taken during completion. A frequently heard comment is "there are 35 or 40 ways to complete a particular well and five of them are bad, so just avoid the bad ones." Yet, the general completion process—the gathering, checking, and analyzing of data and the choosing, designing, and running of the completion—is the same for every well. Completion planning begins before drilling and continues through completion, stimulation, well servicing, and recompletion. The plan must take much information into account to reach the overall goal of every completion: that is, to produce the most oil and gas at the least possible cost. A well-planned completion accomplishes this goal in two ways. First, it recovers the maximum amount of petroleum (economically speaking) by producing reservoir fluids efficiently. Second, it saves possible later costs of equipment, workover, and recompletion through foresight in planning. No matter who plans a completion, reservoir conditions primarily, along with efficiency and foresight, decide the well's success or failure.

Formation Evaluation

In this chapter:

- Evaluating subsurface formations
- Seismic surveys and well records
- Types of logs and measurements
- Identifying producing zones

In the early days of drilling when cable tool rigs dominated, the notion of sampling well bailings to find out what the bit was penetrating not only seemed unimportant but also a waste of time. If a well was going to produce, it would produce—sampling well bailings would not change that.

Today, it is still true that formation evaluation cannot change a well's production potential, but completion techniques suggested by formation data can. Formation evaluation is performed routinely and in more ways than early oil entrepreneurs could have dreamed. Methods for evaluation of subsurface formations now include the sophisticated use of seismic surveys, records from nearby wells, the driller's log, mud logs, core samples, and a multitude of wireline well logs.

Data used to evaluate subsurface formations:
- Seismic surveys
- Records from nearby wells
- Core samples
- Logs

Seismic Surveys

Seismic surveys help in deciding where to drill because they give clues to where pay zones may exist (fig. 2). From a seismic record, the location, depth, and size of potential reservoirs can be predicted. Later, if a formation is found to hold petroleum, its volume can be estimated.

Formation Testing

In this chapter:

- Types of formation tests
- Wireline testing
- Drill-stem tests and tools
- Drill-stem assemblies and procedures
- Surface well testing
- Usefulness of various tests

Formation testing may be done before or after running casing, cementing, and perforating. (The few wells that are completed open hole, of course, are tested only open hole.) Cased-hole completions are tested through perforations. Open hole testing followed up by cased-hole testing is also standard in some areas.

The formation test is the final proof of a well's initial capability to produce oil and gas in paying quantities. Cores and logs tell which formations are likely to produce and where to perforate them, but predictions are not the best data on which to base an expensive completion. However, formation tests in general are most useful in reservoirs with medium to high permeability (greater than 15 or 20 millidarcys). In developed areas where log analysis has proved to be successful in identifying potential completion formations, most operators forego the costs of formation testing.

Wireline formation testers and drill-stem test (DST) tools can be used during or after the conclusion of drilling. Both types of formation tests may be used on a well when considering it for completion.

Formation testing helps determine the production capability of a well and whether the well should be completed.

Completion Design

In this chapter:

- Common aspects of completion design
- Well completion methods
- Single and multiple flow paths
- Completion systems for efficient production
- Economic factors

No two wells are alike. Every good completion design takes into account the uniqueness of a well. It would be difficult to look at every possible completion design, but three items are part of every design process:

- Completion method most suitable for the well
- Completion system chosen to bring the fluids to the wellhead
- Completion cost versus production potential

Completion Methods

The completion method chosen greatly affects the communication from the reservoir to the wellbore.

Basically, there are two methods:

- Open-hole completion
- Perforated completion

In conventional perforated completions, reservoir fluids communicate to the wellbore through perforations (holes) made in the casing and cement. Perforating must be delayed until the cement has properly set and the bond log has been run. In open-hole completions, casing is set and cemented at or near the top of the production interval, and the reservoir is drilled with a bit that is smaller than the inside diameter of the casing. Coal-bed methane wells and horizontal wells are often completed in open hole.

Completion Tools

In this chapter:

- Basic classes of completion tools
- The importance of tubing
- Tubing strength ratings
- Common types of flow-control equipment
- The impact of production methods

Today's oilfield technology offers numerous possibilities for completing a well. While every well is unique and for every well there is a unique completion, all completion designs include certain options. Although a range of modern completion equipment that seems almost limitless provides these options, all completion tools fall under a few basic classes. Each class fills a specific need in completion design. The numerous combinations of these basic tools allow a completion to be tailored to suit the well. These basic tools include tubing, packers, seating nipples, flow-control equipment, erosion-control equipment, wellheads, and when necessary, artificial lift.

Courtesy of Entrac Petroleum: e-Learning Training Specialists

Figure 26. Tubing ready to be run into a well

Tubing

A tubing string is an important completion option and is usually the first consideration in completion design (fig. 26). When used with various equipment options, tubing is the heart of a completion system.

Tubing Strength Ratings

Every type of tubing is assigned American Petroleum Institute (API) ratings for tensile, collapse, and burst strength. *Tensile strength* is the maximum pull that the tubing can bear from its own weight, plus any added pull required to unseat packers or anchors. If the pull is too great, the tubing will stretch until it parts. *Collapse strength* is the maximum

Perforating

In this chapter:

- Perforating methods
- The three stages of stimulation
- Running the completion
- Cleaning up the well

The advent of gun perforating in the 1930s made it easy to shoot round, uniform holes in cemented casing. Until then, passages for formation fluids had to be made in cased, cemented wells with clumsy, unreliable mechanical perforators that slowly gouged each hole needed, sometimes badly damaging the casing in the process. The disadvantages of early perforating techniques made the open hole a common completion choice at the time.

Benefits of gun perforating:
- Less damage to casing (than with the previous method)
- More accurately placed perforations
- Selective perforation of the casing in certain zones

Gun perforating radically changed completion technology. It allowed the entire well to be cased through and specific zones to be produced by means of accurately placed perforations. Acidizing and fracturing techniques almost always work better in wells where the petroleum reservoir is isolated from other formations. Also, multiple zones separated from one another in the same wellbore produce more efficiently. Zone isolation has become a legal requirement in many areas with commingling allowed only with proper request and permission. Effective perforating techniques have helped to make all these things possible.

Originally, gun perforating used actual bullets fired at the casing to penetrate cement and formation rock. It was cheap, effective, and fast. But bullet perforating has pressure and temperature limitations. During World War II, bazooka technology was used to develop jet perforating, which has since become the method of choice for a very high percentage of cased-through completions.

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