ROTARY DRILLING

Casing and Cementing

Third Edition

UNIT II • LESSON 4

ROTARY DRILLING SERIES

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Unit II, Lesson 4
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All who have contributed time, thought, and effort into this book have worked to make this new edition a success in providing the most complete information about casing and cementing.

Units of Measurement

Throughout the world, two systems of measurement dominate: the English system and the metric system. Today, the United States is almost the only country that employs 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, for example, 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 to the SI system, we include the following table.

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)
Thermal gradient	1°F per 60 feet	—	1°C per 33 metres
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

Casing and cementing are essential to drilling oil and gas wells. Lining a hole with casing keeps it from caving in after it is drilled, sealing the wellbore from encroaching fluids and gasses. Cementing the casing in place attaches it firmly to the wellbore wall and stabilizes the hole. Casing and cement both serve additional, important functions in the well. These functions will be addressed later in this manual.

Casing and cementing procedures have grown more sophisticated in recent years as the search for new hydrocarbon-bearing reservoirs takes wells deeper and into more hostile environments (i.e., deep water, high pressures and temperatures, and sour gases). Engineers and metallurgists work continually to refine casing or cementing designs and procedures to handle the challenges associated with offshore and remote locations, extreme depths, and severe conditions.

During the days of cable-tool drilling, numerous strings of casing had to be set as a well was drilled. With the advent of rotary drilling came better quality muds with greater ability to control well pressures. As a result, much more open hole could be drilled. Casing is now generally set to serve a specific purpose and is neither arbitrary nor compulsory for any hole conditions.

Casing

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Casing and tubing account for 15 to 20 percent of the completed cost of a well—often the greatest single item of expense on the well. Failure of casing or tubing results in expensive rework and may lead to loss of the well, or worse, loss of life. Selecting casing sizes, weights, grades, and types of threaded connections for a given situation presents an engineering and economic challenge of considerable importance.

Casing is strong steel pipe used in an oil or gas well to ensure a pressure-tight connection from the surface to the oil or gas reservoir. Casing serves at least seven important functions in the well (fig. 1):

1. It prevents the hole from caving in or washing out.
2. It protects freshwater sands from contamination by fluids from lower zones.
3. It keeps water out of the producing formation.
4. It confines production to the wellbore.
5. It contains formation pressures and prevents fracturing

Figure 1. These joints of casing are ready to be run into the well, where they will serve at least seven important functions.

of upper and weaker zones.

6. It provides an anchor for surface and artificial lift equipment.
7. It provides a flow path for produced fluids.

In offshore operations, casing also provides a conduit from the seafloor to a bottom-supported drilling unit, such as a jackup, on the surface of the water.

Casing Strings

Casing is manufactured in joints that range in length from 16 to 48 feet (ft) or 4.9 to 14.6 metres (m). It ranges in diameter from 4.5 to 48 inches (in.) or 114 to 122 millimetres (mm) or more. Joints of casing are either screwed or (occasionally) welded together as they are lowered into the hole. Several joints of casing, when joined, constitute a *casing string*.

Casing strings are run concentrically, from the surface through the lowest interval with hydrocarbon-bearing potential. The bit drills the hole to a certain depth, then casing is run in to line it and, in most cases, cement is pumped in to bind the casing firmly to the walls of the hole. (Note, however, that there are instances when casing is intentionally left uncemented.) Drilling continues to the next specified depth, and casing is once again run and cemented. This process is repeated until the rig reaches total depth.

Types of Casing

Because casing serves several different functions, it is usually necessary to install more than one string of casing. Typically, a well will require at least three concentric strings of casing: conductor pipe, surface casing, and production casing (fig. 2). Depending on the formations encountered, it may also require intermediate casing. In some cases a liner string may be set and tied back to the surface to form a production string. Each type of casing serves a specific purpose important to the completion of the well.

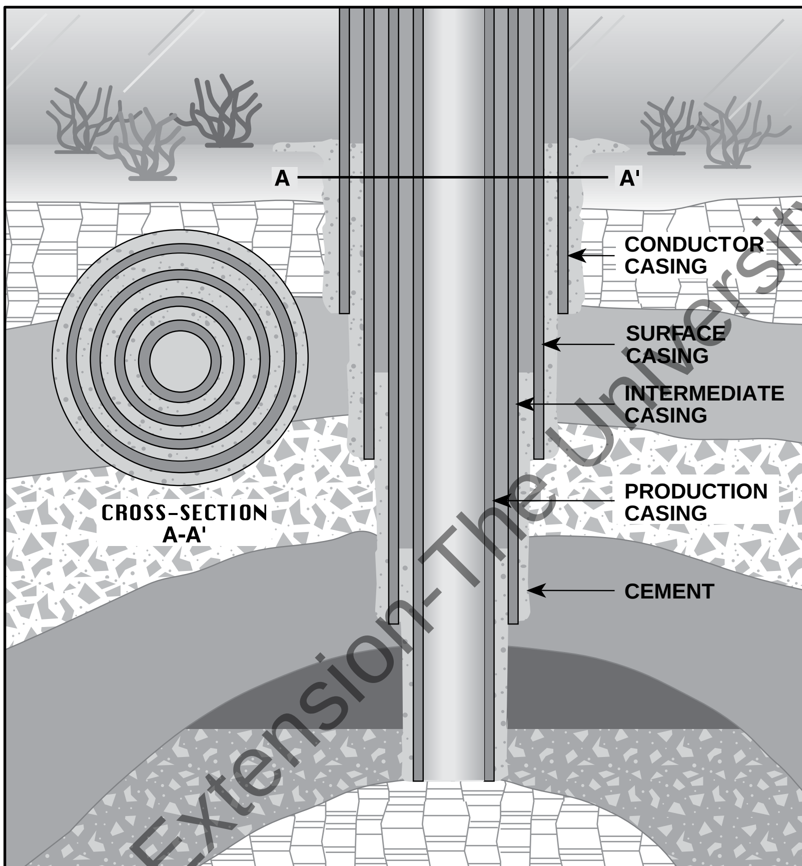

Figure 2. Most wells require several strings of casing, each of which serves a specific purpose important to the completion of the well.

Cementing

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Oilwell cementing is the process of mixing and placing a cement slurry in the annular space between a string of casing and the open hole. The cement sets, bonding the casing to the wall of the wellbore for additional stability.

The practice of cementing began around 1903 in California. Early methods of mixing cement and placing it in the hole were quite crude. Modern cementing practices debuted in 1920, when Erle Halliburton cemented a well in Oklahoma's Hewitt Field for W.G. Skelly (fig. 23). Today, the Halliburton jet mixer remains a basic device for rapid mixing of drilling mud, although it is seldom used for mixing cement slurry.

In 1903 there was only one type of cement and no additives. Today there are eight classes of cement and more than 40 different additives. Bulk-cement handling is standard practice, and blends are tailored to specific jobs. Waiting-on-cement time has been reduced from 10 days to less than 24 hours.

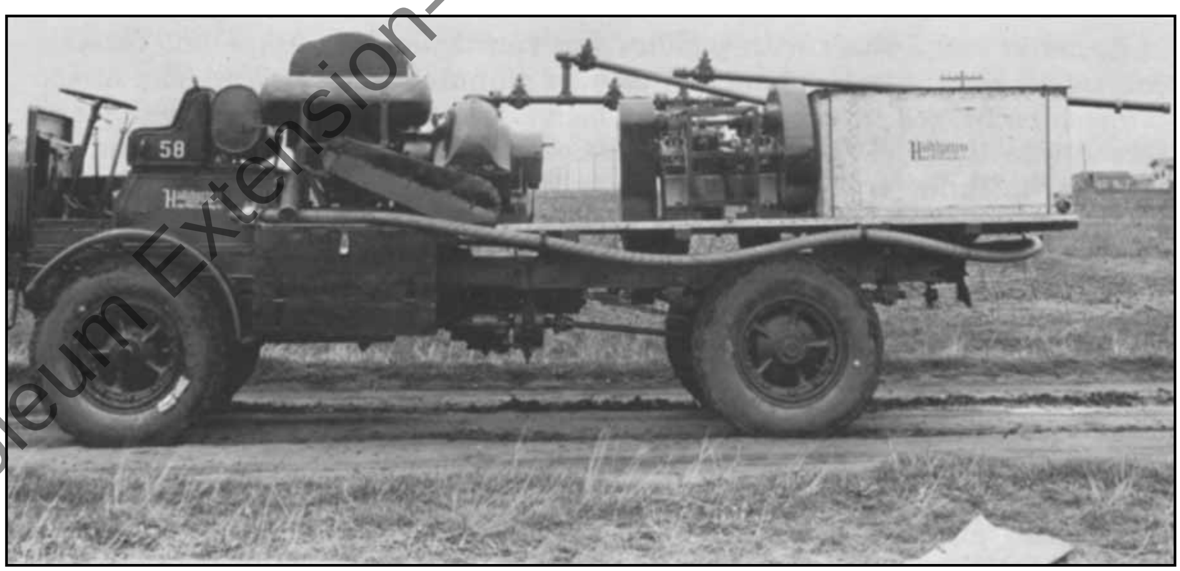

Figure 23. Halliburton cementing equipment from the 1920s (Courtesy of Halliburton)

There are three types of oilwell cementing. *Primary cementing* is performed immediately after the casing has been run into the hole, to seal and separate each zone, and to protect the pipe. *Secondary cementing* is performed after the primary cement job, usually as part of a well servicing or workover operation. Plugging back to another producing zone, plugging a dry hole, and formation squeeze cementing are examples of secondary cementing procedures. *Squeeze cementing* involves forcing cement to the bottom of the casing and up the annular space between the casing and the wall of the borehole to seal off a formation or plug a leak in the casing. Squeeze cementing was introduced in the 1930s and is now a common procedure for plugging perforations or shutting off water. The discussion in this book is limited to primary cementing.

Primary Cementing Basics

Although several methods of primary cementing exist, single-stage and multistage cementing are the most commonly used. *Single-stage cementing*, the most common cementing procedure, consists of pumping a calculated volume of slurry into casing, after pipe has been landed at the desired depth, and displacing the slurry around the shoe and into the annulus in a circulating mode with another fluid (i.e., water, mud, or completion fluid) (fig. 24). *Multistage cementing* consists of pumping cement into the well in two or more separate stages, or batches, behind a casing string. This procedure is used in wells that have critical fracture gradients or that require good cement jobs on long casing strings.

Several functions of primary cementing are:

1. to structurally support and restrain casing;
2. to seal the annulus between pipe and formation against fluid movement from one zone to another and to restrict fluid movement between formations and the surface;
3. to provide well control by weight and rapid curing after protective mud is displaced;
4. to prevent pollution of freshwater formations;
5. to protect the casing's exterior from corrosion; and
6. to protect intermediate casing and liner pipe from torque and shock loads when drilling deeper.

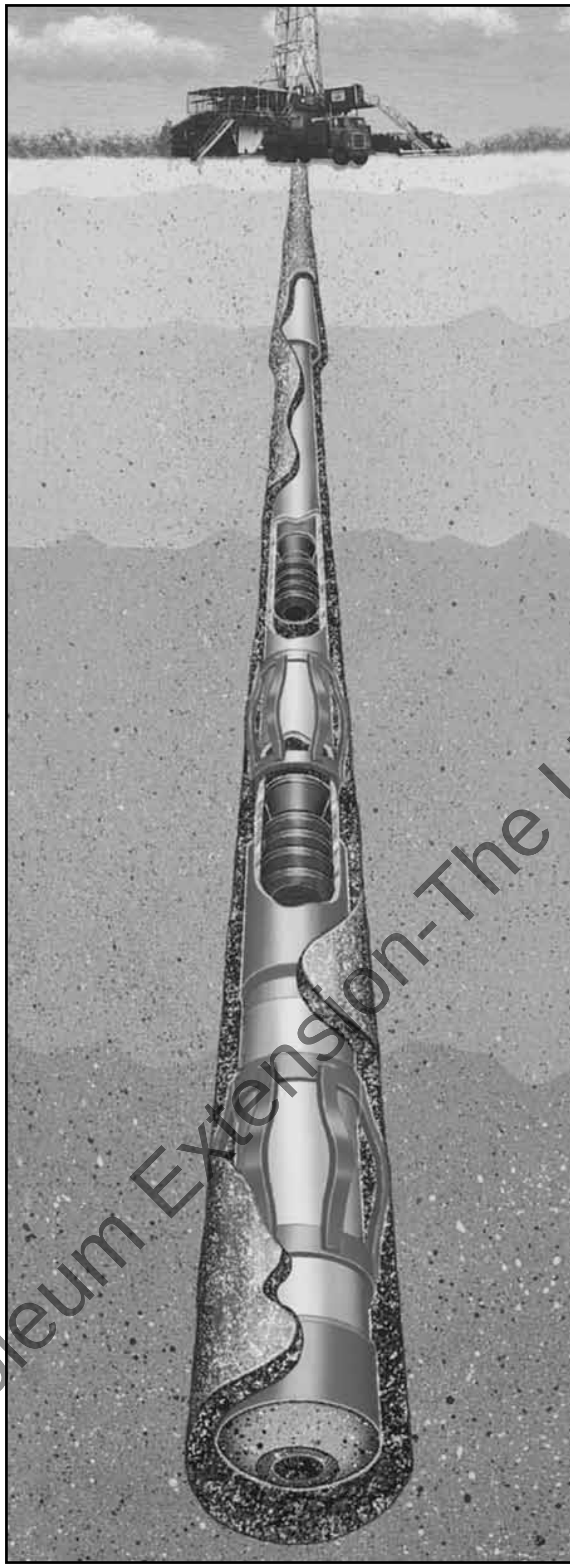

Figure 24. Primary cementing is performed immediately after the casing has been run in the hole, to seal and separate each zone, and to protect the pipe. (Courtesy of Halliburton)

To summarize—

Cement

- supports and restrains casing
- seals the annulus to restrict fluid movement
- provides well control
- prevents pollution of freshwater formations
- protects the casing from corrosion
- protects previously run casing strings from torque and shock loading when drilling deeper

Five factors are important to a good cementing job

- cleaning the annulus without gouging, enhancing cement bonding to the wellbore;
- centering the casing in the hole in order to form a uniform sheath of cement around the casing and minimize the chances of a channeling effect on the cement job;
- strengthening the cement in the annular space to allow for proper perforation in the producing zone;
- bonding the cement to the casing surface to eliminate the possibility of a microannulus; and
- providing the necessary pipe movement, either rotation or reciprocation, to increase turbulence, improve circulation, and provide complete displacement of the drilling fluid with cement.

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