Oil and Gas: The Production Story

The University of Texas at Austin · Petroleum Extension Service

Contents

Introduction

Almost everyone depends on oil and gas—for our cars, in our homes, and at work. Because oil and gas are so integrated in our lives, we should know more about where they come from.

Becoming better informed might sound difficult to do because the oil industry has its own language, technical people, and mystique. With oil and gas thousands of feet beneath the surface of land or water, they are far out of sight and mind of the average person. What occurs in the oil and gas industry aboveground often looks extremely complicated. In reality, the industry is not all that complex, and the basic principles are fairly easy to understand.

This book tells the story of how oil and gas are produced. The story begins with their origin and tells how they are produced today. It continues with the process of bringing the oil and gas up from deep in the ground through wells. You will learn how wells are set up and drilled and about the many processes used in production.

What causes oil and gas to flow from a well? That question is the basis for this story. Inside this book are answers to that and other questions such as:

How are oil and gas handled once they reach the surface?

How are they separated from one another, and why?

How are they prepared for final sale?

You will also learn about the unique problems that can occur when drilling teams embark on oil and gas production. Included in this book are some important solutions to these challenges.

The story you are about to read has no ending; it continues as the oil and gas industry strives to meet our population's growing energy needs.

1

Where Do Oil and Gas Come From?

In this chapter, you will learn:

- The characteristics of reservoir rocks
- How oil and gas are formed
- Where oil and gas are found
- The types of reservoir fluids

One popular idea about the origin of *oil* is that it is found in large underground formations similar to rivers or lakes. Some people think that large subterranean caves or underground rivers are flowing with pure *crude oil*. Nothing could be further from the truth.

There is such a thing as an *oil pool* underground that stores oil. However, it is not an open pool but rather a portion of *rock* that contains *fluids*, called a *reservoir*. This type of oil reservoir is much different from the familiar water reservoirs cities use to store drinking water.

And that is just the beginning of the story. This book contains an interesting account of how oil and gas occur and what happens from discovery to recovery.

Oil and gas are hydrocarbons because they are made up of hydrogen and carbon.

CHARACTERISTICS OF ROCKS

To understand the origin of oil and *gas*, it is necessary to learn something about the basic characteristics of rocks. Most oil is found in rocks. *Natural gas*, often associated with oil, is also found in rocks. Both oil and natural gas are called *hydrocarbons*. They are hydrocarbons because they are made up of two elements: hydrogen and carbon.

The mixture of hydrocarbons forms an oily, thick, flammable *liquid* called crude oil, commonly referred to as *petroleum*. The word petroleum comes from the Greek word for rock, *petra*, and the Latin word for oil, *oleum*. The two words combined literally mean rock oil.

It might be difficult to understand how hydrocarbons such as oil and gas can come out of rocks because few things seem more solid than rock. But some rocks are not as solid as they appear to the naked

2

Exploring and Drilling for Oil and Gas

In this chapter, you will learn:

- How geophysicists use seismology to explore for oil
- How a well is drilled to reach its target
- What drill pipe encounters during drilling
- The precautions drillers take while drilling

EXPLORATION

Although land might look flat and dry on the surface, a hydrocarbon trap could lie deep beneath the surface, even if there is no evidence indicating its presence. This is why it is so difficult for explorers to find hydrocarbon traps.

Explorers of oil and gas traps are called *exploration geologists* and *geophysicists*. These professionals search for subsurface traps that might contain hydrocarbons. One of the sciences they use in their search is *seismology*.

Seismology is the study of natural and man-made vibrations in the earth. The vibrations take the form of sound waves. For example, earthquakes create sound vibrations that can be studied using seismology. Scientists can also study sound vibrations imposed on the earth's surface using force. In both cases, the sound waves can be recorded on a chart and studied for clues in locating traps.

Seismic exploration studies sound wave vibrations as they travel through rock layers.

To understand how these sounds point to traps, consider the way voice sound waves travel outward and back when a person shouts toward the face of a cliff or building. The sound travels through the air, bounces off the cliff or wall, and returns back as an echo. The same basic principle applies to *seismic* waves used to explore for petroleum traps but with some differences.

In seismic exploration, geophysicists search for traps buried deep below the surface, so the sound must travel down through thousands of feet of rock and back up to the surface. To increase the chances of finding a potential reservoir, geophysicists usually perform seismic surveys over many miles of surface area.

3

Drilling Wells Offshore

In this chapter, you will learn:

- How to drill for oil at sea
- The unique facilities constructed for work offshore
- The challenges presented by the environment
- How drillers reach oil and gas targets in deep water

Offshore operations have expanded in the last few years with platforms actively producing oil and gas in thousands of oceanic locations around the world. Today, offshore operations rely heavily on advanced technology and skilled workers to drill under challenging conditions in remote locations.

There are two main types of offshore facilities: *offshore rigs* and *production platforms*. Sometimes, a platform contains both rig and *production* operations. The rig performs the drilling process to reach the oil and natural gas. The production platform is a much larger structure that produces the oil and natural gas and houses workers and production equipment.

A wide variety of platform installations populate waters around the globe. They house workers and equipment that work around the clock to drill and produce oil and gas, and then transfer the production to shore.

PLATFORMS

An offshore production platform can be secured to the seafloor or it can float on the surface. The type of offshore facility depends on the operation's distance from shore, the depth of the water, and the size of the area to be drilled. Much of the drilling equipment on platforms is similar, but installation of platforms can vary dramatically (fig. 3.1). Some facilities are mobile and can be floated or moved to various locations. Others might be permanently anchored to the seafloor. Most offshore facilities have a *helideck* used by helicopters to transfer crews, load equipment, and deliver supplies.

An offshore drilling rig creates the opening by which oil and gas can be produced. Rigs can also be used to prepare for production.

4

Testing and Completing Wells

In this chapter, you will learn:

- What happens when pipe reaches the producing zone
- The importance of reading a well log
- Test methods that reveal downhole information
- Steps to complete a well
- How fluids are drawn out of rock and up a well

It costs a lot of money to drill a well and even more to complete one. If well owners are going to bear the expense, they need to know whether there are enough hydrocarbons in the trap to justify *completion*. The cost of completing the well varies from year to year. On average, for every seven exploratory, or *wildcat*, wells drilled, six of them will be dry; meaning, only about one in seven strikes oil or gas. These are poor odds, but one good reservoir can make the payoff worthwhile. Once the hole is drilled into the reservoir, the well owners will run tests to see if hydrocarbons are present before they proceed.

Completing a well is costly, so drillers need to know if hydrocarbons are really present.

FORMATION TESTING

One way to test the formation in a well for the presence of hydrocarbons is to log it. *Well logging* is a method of obtaining and recording downhole information about the well. It involves lowering a special logging instrument into the well that sends signals to the surface where electrical, radioactive, or acoustic properties of the formations are recorded. This record is called a *log* and is expressed in several lines or curves (fig. 4.1). Experts can look at the curves and fairly accurately determine whether a formation has petroleum and how much it might have.

Another way to test a well is to take *core samples* of the formation. A core is simply a long cylinder of rock that is relatively small in diameter. It is extracted from a formation using a special coring drill.

5

Stimulating Reservoirs

In this chapter, you will learn:

- What causes formation damage
- How to achieve reasonable flow rates
- Methods of initiating flow
- How to open new channels of flow

Natural and man-made formation damage can slow down a well's rate of flow.

Petroleum and other fluids such as water reside in the pore spaces of reservoir rock. These pore spaces must be connected and permeable so the fluids can flow out of the rock and into the well. Sometimes, a reservoir rock has low permeability and the hydrocarbons cannot be extracted at reasonable rates.

Another factor that slows the rate of extraction is man-made *formation damage* caused by drilling into the rock. The rock's natural permeability might be adequate, but when a well is drilled into the reservoir, it can cause damage to the surrounding area and reduce the permeability of the nearby formation.

There are many other causes of formation damage. The drilling mud used in drilling the hole can cause problems. When the mud contacts the formation, it sometimes seeps into the rock and blocks permeability (fig. 5.1). Or, the water in the mud can do the same when it interacts with rock minerals. In both cases, hydrocarbons cannot readily flow into the well.

Because various problems can threaten the rate of extraction, it is beneficial for explorers to obtain as much data as possible to maximize production. One way this is done is through *reservoir modeling*. This technique creates a computerized model of the reservoir from digitized data of geologic maps and engineering studies. The data is entered into a computer program that applies past and present values for types of reservoir behavior to create a model of the region. The computer model predicts behavior over time and facilitates decisions about how to stimulate production of the fluids. When *stimulation* is recommended, two common techniques are used: *fracturing* and *acidizing*.

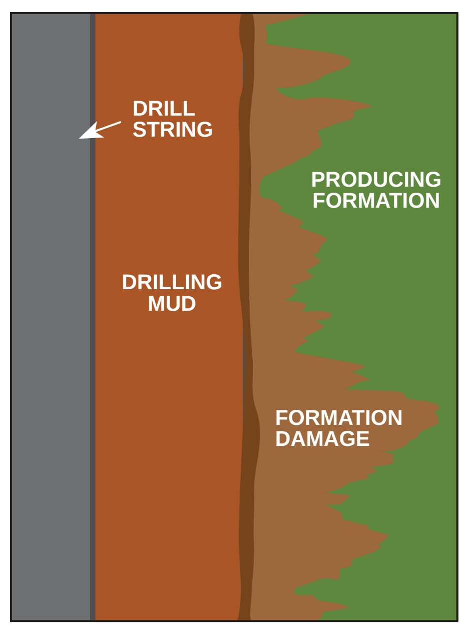


Figure 5.1 When the hole is being drilled, drilling mud can seep into a permeable formation.

7

What Controls the Well?

In this chapter, you will learn:

- What makes up a wellhead
- How wells are controlled
- How the equipment is controlled
- About managing high- and low-pressure wells

On the surface, various types of specially designed equipment are hard at work. The *wellhead* is the equipment that confines and controls the flow of fluids from the well. Wellheads vary in size, strength, and configuration, depending on conditions. A wellhead sometimes consists of several heavy fittings with certain parts designed to hold high pressures. Such a wellhead is used on a high-pressure gas well. Or, a wellhead might be a simple assembly designed to support tubing in the well when pressure and production are low. Generally, wellheads are made up of one or more *casingheads*, a *tubing head*, and a *Christmas tree* (fig. 7.1).

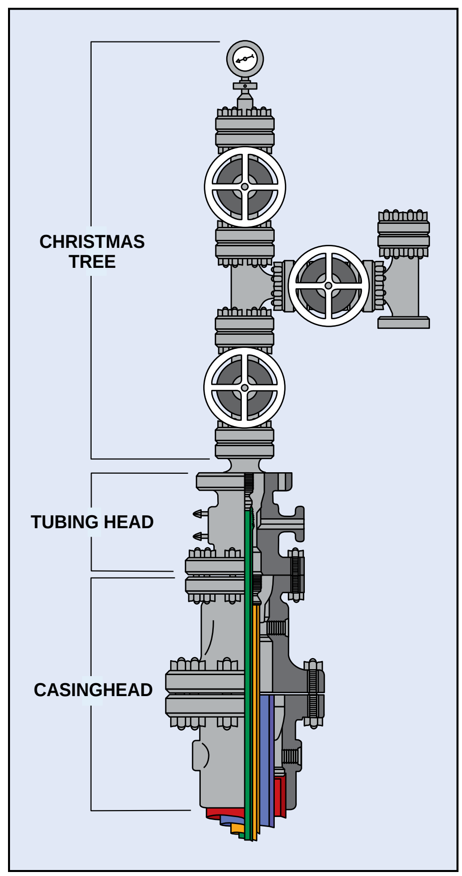


Figure 7.1 A typical wellhead is made up of one or more casingheads, a tubing head, and a Christmas tree.

CASINGHEAD

A casinghead is a heavy flanged steel fitting connected to the first string of casing. It provides housing for assemblies, allows suspension of the casing strings, and prevents fluid flow as necessary. A casinghead has several parts attached to the top of each casing string after they are run and cemented in the well. In wells with an intermediate casing string, two casingheads can be used, one on top of the other (fig. 7.2). In wells having only an outer surface casing and inner production casing, the casinghead might be less complex (fig. 7.3).

Regardless of type, the casinghead enables the use of gripping devices, or *hangers*, to help support the weight of the casing. Casingheads also have sealing elements or packers to prevent the flow of fluids within the casinghead and to the atmosphere. Openings are provided to bleed off pressure that might collect in or between casing strings.

8

Lifting More Oil and Gas

In this chapter, you will learn:

- About the limits of natural energy
- How to bring up more oil
- How a beam pumping unit works
- When to use gas lift

As a well produces, pressure in the reservoir will likely fall to a point where *natural drive energy* is not strong enough to push the oil and gas. At this point, some method of artificial lift must be used. Although there are many different methods of artificial lift, they can be divided into two broad categories: pumps and gas lifts. Pumping methods include three primary types: beam, subsurface hydraulic, and electric submersible.

Two common ways to lift oil: pump pressure and *gas injection*.

BEAM PUMPING

The most common method of artificial lift is *beam pumping*, which operates equipment both on and below the surface. A *beam pumping unit* consists of a pumping unit, a sucker rod string, and a sucker rod pump. Beam pumping units are a familiar sight around *oilfields* (fig. 8.1).

On the surface, the beam pumping assembly imparts an up-and-down, rocking motion from the *walking beam* to a string of high-strength steel rods called *sucker rods* (fig. 8.2). The sucker rods are attached to the front of the pumping unit. These rods go down inside the tubing and are attached to the top of a *sucker rod pump*. The pump is installed inside of, or as a part of, the tubing string near the bottom of the well (fig. 8.3). As the walking beam moves up and down, the rod string also moves up and down to operate the sucker rod pump.

9

Recovering the Rest of the Oil

In this chapter, you will learn:

- How to tap even more oil
- Different techniques to drain a reservoir
- How water and heat assist processes
- The challenges of enhanced recovery

At some point, a well can no longer produce oil, even when artificial lift methods are applied. But this does not mean that no oil remains in the reservoir. Statistics show that from 25–95 percent of the original *oil in place* might still be there. Even the most efficient water drive can leave behind 75 percent of the oil. The U.S. Department of Energy estimates that 24–45 billion barrels of recoverable oil still remain in initially produced reservoirs—meaning, those reservoirs that have been produced at least once before. This estimated amount more than doubles the current known reserves in the United States.

Even after successful production, a reservoir might still contain one-fourth to over three-fourths of the original oil accumulation.

To recover more oil from produced reservoirs, the petroleum industry has developed a number of alternate recovery methods to produce oil still residing there. These techniques are known as *enhanced oil recovery* (*EOR*), *secondary recovery*, and *tertiary recovery* (fig. 9.1). The definitions of these terms vary and overlap.

10

Separating and Treating Reservoir Fluids

In this chapter, you will learn:

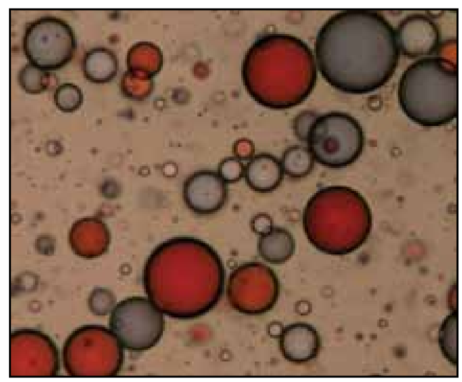
- How oil and gas are processed for sale
- The different vessels used for separation
- How separators divide fluids
- Why it is important to remove water

When gas, oil, and water reach the surface, what happens next? Before they are ready for sale to a pipeline company or other shipper, they must be processed. Crude oil and natural gas seldom come out of a reservoir in a pure state. What actually comes out of a producing well is a relatively complex mixture of liquid, gas, and solids made up of mostly sand and *scale*, called *basic sediment*. *Basic sediment and water (BS&W)* must be removed, and the oil and gas must be separated.

Once separated, the oil goes to a refinery where it is used to make gasoline, kerosene, fuel oils, and other products. The gas is piped to a special plant for more processing to extract natural gas, propane, butane, and other hydrocarbons. The water, although once helpful in the reservoir, must be removed and handled properly when it reaches the surface with the oil and gas. Because it is usually salt water, it must be properly disposed of so it does not harm the environment. Often, the water can be recycled in water drives and injected back into other reservoirs to lift up more oil.

Produced water occurs in two ways: as *free water* that rapidly settles out of oil that has remained still in a tank; or as water closely bound up in the oil. Closely bound water forms an *emulsion,* which is a mixture of droplets of one liquid spread out, or dispersed, in another liquid. In an emulsion, liquids do not mix well.

An *oilfield emulsion* usually has water droplets spread out and suspended in the oil (fig. 10.1). The droplets eventually settle out if given enough time, or the process can be sped up by applying heat, chemicals, and other techniques.



Courtesy of Nicolas Bremond/LCMD-ESPCI

***Figure 10.1** This photomicrograph shows droplets of water suspended and dispersed throughout the oil in a water-in-oil emulsion.*

11

Understanding Well Performance

In this chapter, you will learn:

- The importance of testing
- Different testing methods
- What the tests indicate about production

Production tests help determine how much or how fast a well will produce. A well owner might request that several production tests be run to reveal important information about the well and its reservoir. To ensure the well produces efficiently and to build a case history, several different types of tests can be conducted.

Best results are achieved when drillers know exactly how a well will behave.

POTENTIAL TESTS

The most frequent well test is a *potential test*. This test measures the largest amount of oil and gas a well can produce under certain fixed conditions over a 24-hour period. The test involves allowing the well to produce for a time period and accurately measuring its production. Potential tests are performed when the well is first produced and throughout its producing life.

Production from the well is measured in several ways. One approach uses a *test separator* and stock tank. A test separator is simply one that diverts the well fluids through the separator testing system while the well is being tested (fig. 11.1). In a test separator, fluids are divided into oil and gas. The exiting gas is piped through a meter and measured.

12

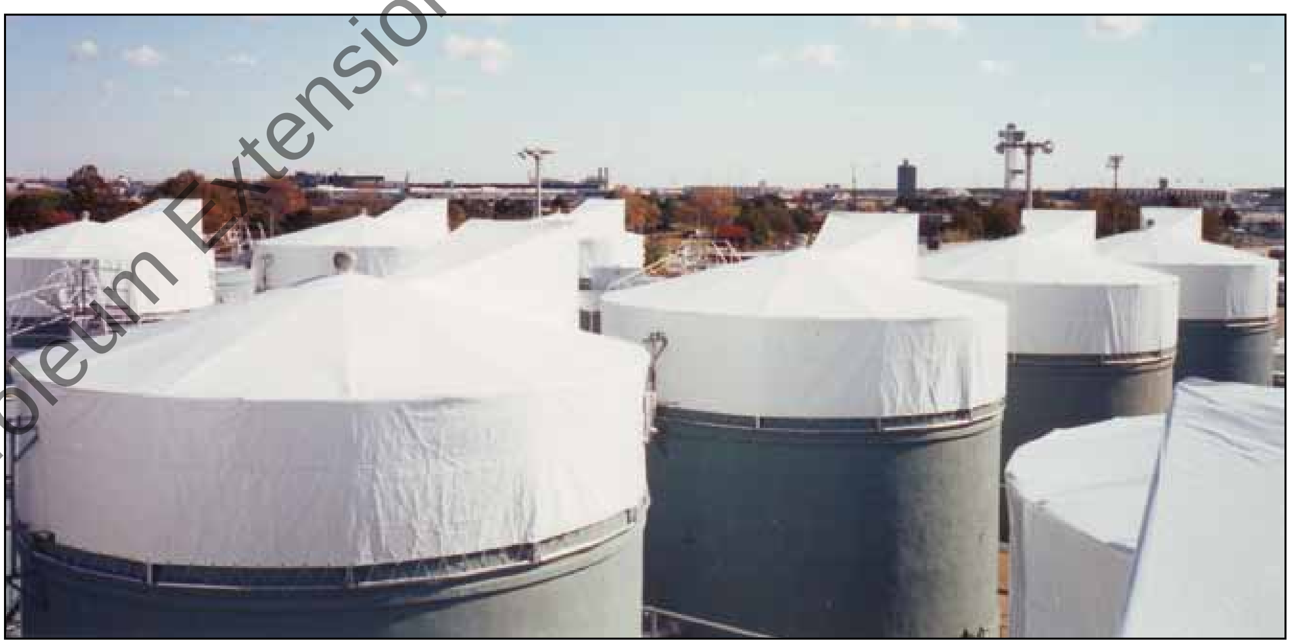
Storing and Measuring Oil and Gas

In this chapter, you will learn:

- How stock tanks are used
- The importance of accurate measurement
- The effect of temperature and water on volume
- How a LACT unit operates
- The impact of computers

STORAGE

Stock tanks on a lease are a frequent sight. These tanks store oil until it is sold and moved by pipeline or other transportation to a refinery. Often, several stock tanks are placed near one another, forming a collection of tanks, often referred to as a *tank battery* (fig. 12.1).



Courtesy of Rubb, Inc.

Figure 12.1 A top view of a tank battery

13

When Special Problems Occur

In this chapter, you will learn:

- How water can affect equipment and pipes
- Why water must be properly handled
- What happens when paraffin accompanies oil
- The dangers of hydrogen sulfide

Given that well fluids on a lease are handled and treated in a continuous operation, certain problems will sometimes develop. Some of these conditions were mentioned in earlier chapters but because of their impact on well performance, they are discussed here in more detail. Some of the major problems that might occur are corrosion and scale caused by water, paraffin, and *hydrogen sulfide* gas. Specifically, produced salt water is a source of many problems.

CORROSION

As oilfields get older, more and more water is produced from them, and increased water production means increased corrosion problems. Fighting corrosion is possible with special chemicals called *inhibitors*. Research has helped industry develop inhibitors that protect against corrosion at a reasonable cost. Most liquid *corrosion inhibitors* are effective at holding down or eliminating corrosion.

It is best to place a corrosion inhibitor in the well fluids as they exit the reservoir. There, the inhibitor mixes with the fluids and goes to work immediately at the bottom of the well. As the fluids flow up the tubing and into the rest of the production system, the inhibitor is already working in the fluid stream.

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