Crude Journey

BY DAVID HOLZEL

GETTING OIL FROM THE GROUND TO THE GAS TANK IS PART GEOLOGY, PART CHEMISTRY, AND INVOLVES THOUSANDS OF MILES OF PIPELINES AND A WORLDWIDE TANKER FLEET.

The oil derrick and the gas pump don't readily come to mind as objects of beauty. But, if they disappeared tomorrow, the world would be unrecognizable. The two structures are visible reminders of the source of much of the world's wealth–the petroleum economy.

Oil provides about 40 percent of the energy Americans consume and 97 percent of the country's transportation fuels, according to the U.S. Department of Energy. It's impossible to understate the importance of oil in the United Kingdom, which uses 1.7 million barrels a day throughout its economy, or in Australia, which consumes 880,000 barrels a day. U.S. neighbors Canada and Mexico use 2.33 million barrels a day and 2.04 million barrels a day, respectively. The United States consumed an average of about 20.4 million barrels of oil per day during the first ten months of 2004, up from 20.0 million in 2003. Of this, motor gasoline consumption was 9.0 million barrels a day or 44 percent of the total. Petroleum demand in 2005 is projected to grow by just 1.4 percent (280,000 barrels per day), to an average 20.7 million barrels per day, in response to the combined effects of somewhat slower economic growth and relatively high crude oil and product prices.

These statistics may come as no surprise. But what most people don't have a handle on is the process that takes the fossil remains of one-celled prehistoric sea plants and animals and transforms them into a dizzying array of products–not just gasoline and jet and diesel fuel, but plastic beverage containers, mascara, heart valves, floor polish and even bubble gum.

So how do oil companies find petroleum? How is crude oil processed into usable products? And how does the product with the highest demand–gasoline–get to the pump? Let's take the journey between the derrick and the gas station.

PROSPECTING FOR OIL

Finding oil is the work of geologists. There are a number of ways oil companies search for new oil fields. A representative of Chevron Corporation explains that prospectors look for a "convergence of geologic elements." Some of the elements, he explains, include:

"Source rock to generate hydrocarbons, a porous reservoir rock to hold them, and a structural trap to prevent fluids and gas from leaking away. Traps tend to exist in predictable places–for example, along faults and folds caused by movement of the Earth's crust or near subsurface salt domes."

Geologists have a number of high-tech tools to aid their search for underground oil. Satellite imaging aids in the analysis of surface rock. Magnetometers and gravity meters can detect subtle changes in the Earth's magnetic and gravitational fields, an indication that oil may be present. And seismic surveys, performed by sending shock waves underground and measuring the waves reflected back to the surface, can help draw a picture of the terrain below the surface.

Despite all these tools, the only way to confirm the existence of oil below ground is to drill. "The average U.S. wildcat well (an exploratory well drilled a mile or more from existing production) has a one in 10 chance of striking hydrocarbons," according to Chevron.

PUMP IT UP

Oil rigs are structures containing the equipment needed to drill for oil. Rigs include the derrick, the tall structure that holds the drilling apparatus; the rotating equipment, at the end of which is the drill bit, which cuts deeper into rock; an engine to run the rotating equipment; a circulation system that pumps drilling mud to lubricate and cool the drill bit and the steel pipes attached to the drill bit; and casing, a concrete pipe that lines the drill hole, keeps the hole from collapsing and allows the drilling mud to circulate.

To prevent blowout–an uncontrolled gush of oil or gas to the surface–high-pressure valves are installed to seal the drill lines. The valves can relieve pressure when necessary.

Once the well has been drilled, the oil is caused to flow by dissolving and fracturing the rock at the bottom of the well. The substance used to dissolve the rock varies, depending on the type of rock. Once the oil is flowing, the rig is removed and replaced by pumping equipment which will remove the oil.

The oil pump is placed at the well head. The pump is run by an electric motor that forces the pump up and down, creating a suction in the well that draws the oil up.

REFINING

Once crude oil has been pumped, the job changes from one of geology to chemistry. Crude oil consists of different kinds of hydrocarbons – sometimes in the hundreds – each with its own molecular structure of carbon and hydrogen atoms. The work of an oil refinery is to break the crude oil down into its different parts and then reconfigure them to create usable products.

The refining process has three steps: separation, conversion and treatment.

- Separation takes crude oil and breaks it into components, called "fractions," based on the component's weight and boiling point. Oil is piped through hot furnaces, where lighter components rise to the top and heavier ones sink to the bottom.

RECOVERY METHODS

Before the development of advanced recovery procedures, it was common to leave 90 percent of the available oil in the reservoir due to the inability to bring it to the surface. However, advanced technology now enables producers to bring 60 percent of the available resources to the surface. There are three recovery methods used to bring oil to the surface.

- Primary recovery first relies on underground pressure to drive fluids to the surface. When the pressure falls, artificial technology is used. This can include using pumps, or pumping units. Primary recovery often tops only 10 percent of the oil in the deposit.

- Secondary recovery uses water to bring more oil to the surface. With this approach, water is injected into the oil-bearing formation. This maintains underground pressure and pushes still more oil towards the producing wells. This can bring an additional 20 percent of oil in place to the surface.

- The third step is to utilize enhanced recovery techniques to mobilize the remaining oil. There are three common approaches: 1.) thermal recovery, which entails injecting steam into the formation; 2.) gas injection, which utilizes gases to lower the viscosity of oil and increase flow; and 3.) chemical flooding, which involves mixing dense, water soluble polymers with water and injecting the mixture into the field. These techniques are used to bring as much as 60 percent of the reserve to the surface.

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Gasoline is among the lighter components, with a boiling range of 104 to 401 degrees Fahrenheit depending on the many compounds found in the gasoline. Such light fractions rise to the top of distillation towers as vapor and, once separated from the other fractions, condense back to liquids.

- Conversion essentially splits molecules to create higher-value products. "The most widely used conversion method is called cracking because it uses heat and pressure to 'crack' heavy hydrocarbon molecules into lighter ones," according to Chevron. "A cracking unit consists of one or more tall, thick-walled, bullet-shaped reactors and a network of furnaces, heat exchangers and other vessels."

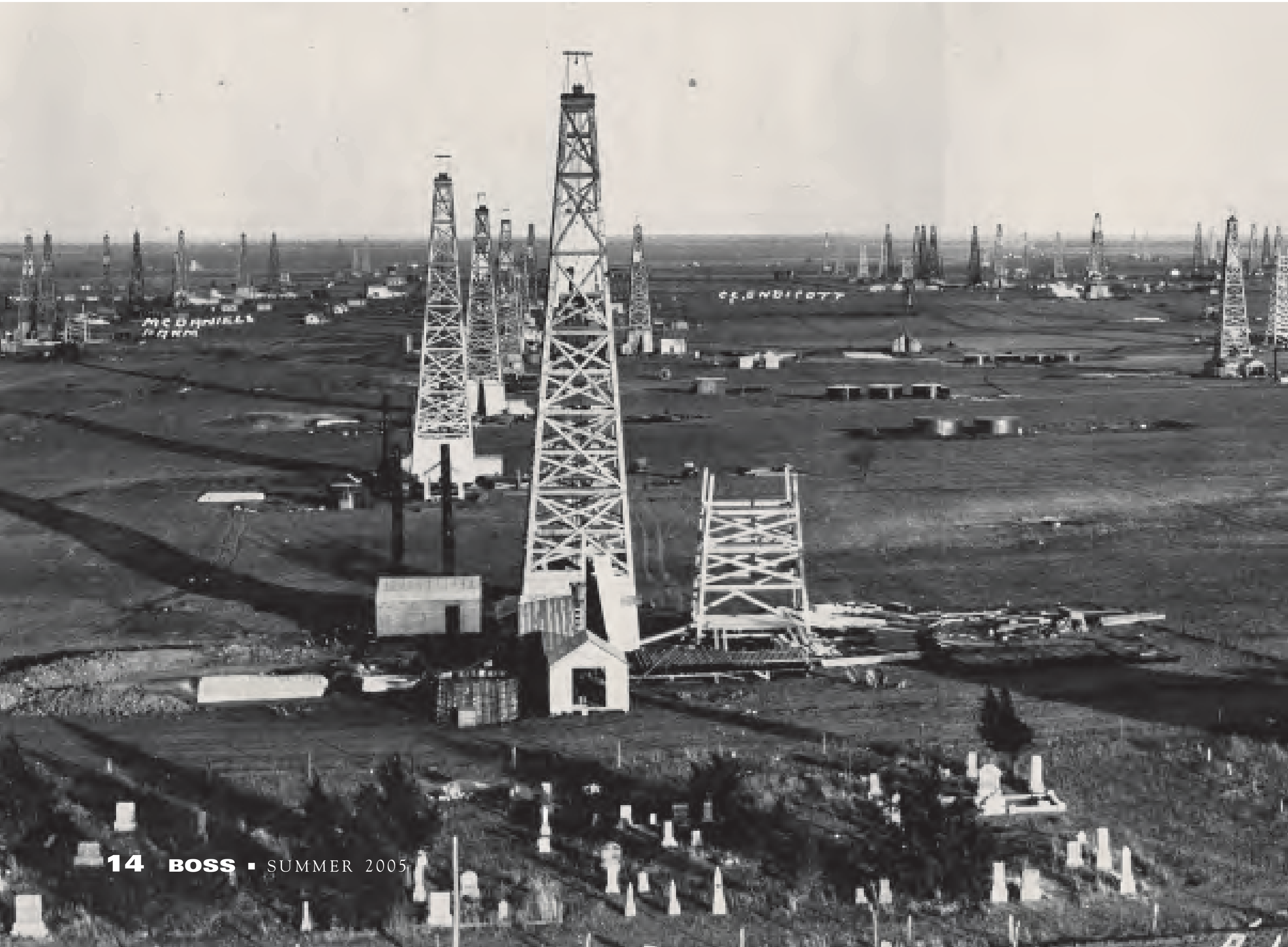
When the goal is to create gasoline, the process is called fluid catalytic cracking, or "cat cracking." It converts heavier fractions into smaller gasoline molecules using heat of about 1,000 degrees Fahrenheit, low pressure and a powdered catalyst–a substance that accelerates chemical reactions, according to Chevron.

- During treatment, hydrocarbon molecules are combined with other chemicals, known as additives, to form a finished product. When that product is gasoline, considerations include octane and vapor pressure ratings.

TRANSPORTING

According to a report by Dr. Jean-Paul Rodrigue, professor at the Université de Montréal, "each year, about 1.9 billion tons of petroleum are shipped by maritime transportation, which is roughly 62 percent of all the petroleum produced. The remaining 38 percent, is transported either using pipelines, trains or trucks. Most of the petroleum follows a set of maritime routes between regions where it is being extracted and regions where it is being refined and consumed.

Three Sands Oil Field, Tonkawa, OK 1921



About half the petroleum shipped is loaded in the Middle East and shipped to Japan, the United States and Europe. Tankers bound for Japan use the Strait of Malacca while tankers bound for Europe and the United States will either use the Suez Canal or the Cape of Good Hope, pending the tanker's size and the destination."

"The world tanker fleet capacity (excluding tankers owned or chartered on long-term basis for military use by governments) was about 280 million deadweight tons in 1996. There are roughly 4,000 tankers available on the international oil transportation market. Transportation costs thus account for about 5 to 10% of the added value of oil," reports Rodrique.

SHIPPING

It is hard to understate the size and capacity of a typical vessel that transports oil. The world's largest tanker, *Jahre Viking*, is 1,504 feet long and 226 feet wide. It is so long that if the Empire State Building could be laid along its deck, the ship would have 253 feet of deck space to spare. The *Jahre Viking* can carry 4.1 million barrels of crude oil–about 172 million gallons.

The next time you're filling up the tank, you might consider the incredible journey – of geologists, chemists and tanker pilots – that makes your journey possible. ■

OIL AND WATER: OFFSHORE DRILLING

Finding oil beneath the sea is more difficult than prospecting on land, but requires the same analysis of seismic survey data and exploratory drilling. Likewise, offshore drilling operates much the same as drilling on land, but with rigs adapted to float or rest on the sea floor. There are several types of rigs:

Platform

An immobile structure that rests on the sea floor. Built of concrete or steel, platforms can be used as permanent pumping sites and often are much larger than other types of drilling rigs.

Semi-submersible

A floating unit containing pontoons that, when filled with seawater, submerge to a predetermined level and cause the unit to sit low in the water. Much of the structure sits underwater. Anchors hold the unit in place until it is ready to be moved to the next drilling site.

Jack up

A mobile unit that sends legs to the seabed, raising the rig out of the water.

Drill ship

These units can sail to a drilling location under their own power and then begin drilling.

Once oil is discovered, the drilling rig is generally replaced by a platform which is assembled at the drilling site. Depending on the area to be drilled, the depth of the water and distance from shore, the platform will vary in size, shape and type.

The platforms are made of steel that house all the processing equipment and are fixed to the sea bed. In addition, the platforms need to accommodate up to 80 workers who typically work a 12-hour day, one week on and one week off. Concrete tanks hold oil pumped from the offshore well. The world's biggest platforms are bigger than a football field and rise above the water as high as a 25-story building.

Once retrieved, the crude oil is transported to land through deepwater pipes or by worldwide tank transfers.

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- Hose Clamps
- Valves
- Hydraulic Couplings
- Dry Disconnect Couplings
- Gauges

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Oil Facts

How many gallons are in a barrel of crude oil?
42

How much crude oil does it take to make a gallon of gasoline?
Some refineries can turn more than half of every barrel of crude oil into gasoline—more than 21 gallons. Seventy years ago only 11 gallons of gasoline could be produced.
(Source: Chevron)

What does crude oil look like?
Crude oils vary in color, from clear to tar-black, and in viscosity, from water to almost solid.
(San Joaquin Geological Society)

Countries with the Highest Oil Reserves as of January 1, 2005 (Billion Barrels)

Saudi Arabia	261.90
Canada	178.80
Iran	125.80
Iraq	115.00
Kuwait	101.50
United Arab Emirates	97.80
Venezuela	77.23
Russia	60.00
Libya	39.00
Nigeria	35.26

Source: PennWell Corporation, Oil & Gas Journal, Vol 102, No. 47 (December 20, 2004).

A 37.5 million gallon vessel carrying refined oil…

- Is enough oil for 300 jet flights from London to Houston.
- Allows 200,000 cars to drive from New York to Los Angeles and back.

Country	Demand[1]	Total net imports[3]	Oil in Reserve[4]
United States	20.25	11.75	21.891
Mexico	2.04 (2004 average)	-1.63	14.6
Canada	2.33	-1.05	178.8
Australia & New Zealand	1.05 (2004 average)	1.491	N/A
Japan	2.93	6.05	.059
France	2.01	1.89	.146
Germany	2.43	2.55	N/A
Italy	1.76	1.71	.622
United Kingdom	1.70	-0.442	4.487
European Countries[2]	7.22	3.70	9.34
	millions of barrels per day		billions of barrels

1 - United States: EIA, Petroleum Supply Monthly, March 2005. Other OECD Countries: IEA, Monthly Oil Data Service, April 12, 2005.
2 - Other European countries consists of Austria, Belgium, Czech Republic, Denmark, Finland, Greece, Hungary, Iceland, Luxembourg, the Netherlands, Norway, Poland Portugal, Slovakia, Spain, Sweden, Switzerland and Turkey.
3 - United States: Energy Information Administration (EIA), Petroleum Supply Monthly, March 2005. Other OECD Countries: International Energy Agency (IEA), Monthly Oil Data Service, April 12, 2005.
4 - PennWell Corporation, Oil & Gas Journal, Vol 102, No. 47 (December 20, 2004)