OFFSHORE DRILLING AND PRODUCTION

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Summary

Since the beginning of the petroleum industry, oil and gas reservoirs had been discovered on land fields. However, at the end of the 19th century reserves discovered near shore initiated the offshore petroleum industry. In this work, a brief reference to the offshore exploration and production shows how technology has evolved for recovering reserves.

Nowadays, economics and demand have justified exploratory and developmental phases in offshore fields located in the Gulf of Mexico, the North Sea, West Africa, the northeast coast of Brazil, Australia, and other regions around the world. For each field, there are many options for the development system that will allow hydrocarbon production to be brought to the market.

Designing and deploying the system will depend on many factors, such as water depth, surface/underwater conditions, available infrastructure, etc; therefore the available types of development systems are fixed platforms, floating vessels, floating structures, and subsea systems.

The general process to drill and complete an offshore well is described, considering key aspects such as well control and some of the most common problems during the drilling stage. Some considerations for wells located in deep and ultra-deep water beyond 10000 ft (3050 m) are mentioned.

Offshore production is mentioned as one important step to attain the final product: marketable oil and gas. The separation process is necessary because hydrocarbons flow from reservoir along with unwanted components such as water and solids. The conditions of the multiphase production environment and the production system during the field life are also considered to assure the flow from subsurface to the sale point on surface.

Although subsea wells require operation reliability, the last topic of this work relates the potential well intervention needed for an undesirable condition or enhancing the production for this type of wells.

1. Introduction

Since late 1890s, independent companies have tried to access oil and gas from offshore fields when they realized hydrocarbon reservoirs extended off the shore. By that time, they had already developed some drilling and production systems for onshore fields.

Offshore operations began in the East Coast of the USA, where wooden "platforms" with derricks and along with other facilities on the surface aided hydrocarbon production in shallow waters of depths of 30-40 ft (9-12 m). Due to environmental issues, the oil industry reduced its presence in the East Coast and focused on the Gulf Coast and Lake Maracaibo, Venezuela.

From the 1900s to the late 1940s, the first offshore technologies were developed in these areas. The technology included structures constructed from wood, concrete or steel pilings, and designs from the nautical industry, such as ships and submersible barges. It was after the 1940s that systems for more than 40 ft (12 m) of water were designed and implemented for offshore petroleum exploration and production. See Appendix 1.

When	Who	Where	What
1897	H.L. Williams	Summerland, CA	Three wooden piers out some 450 yards from the shore, with derricks atop the piers and other equipments. 35 ft of water
1900s		Elwood field, California Coast	Piers and derricks extended 1,800 ft from the shore. 30 ft of water
1910s-1950s	Gulf Oil Co.	Lake Caddo, TX	Wooden (cypress) pile platforms for derricks and pipe racks for producing gas
1920s	Lago Petroleum	Lake Maracaibo, Venezuela	Concrete platform pilings with steel heads, using steel cable for structural integrity
1932	Indian Oil Co.	Rincon, CA	Stand-alone platforms on shallow waters of the Pacific Ocean
1930s	Texas Company	Louisiana swamps	Standard submersible barges, *Giliasso's* design, with a platform weld on top and then a derrick. This began the mobile offshore drilling because barges could quickly move to new locations
1930s	Humble Oil Co.	McFadden Beach, TX	Platform using pilings and rail roads to haul equipment and supplies. 100 ft from shore
1937	Pure Oil Co. & Superior Oil Co.	Coast near Creole, LA	Platform atop timber pilings, 14 ft of water and 15 ft above water. Supplies and crew were hauled with boats
1946	Magnolia Petroleum Co.	Morgan City, LA	Conventional platform design on steel pilings. 16 ft of water, six miles from shore
1947	Superior Oil Co. & McDermott Co.	Creole Field, Gulf of Mexico	First prefabricated steel tubular structure built onshore yard and barged to the site, 18 miles off the Louisiana coast. 20 ft of water
1947	Kerr-McGee Co. & Brown & Root	Ship Shoal Area, Gulf of Mexico	Combination of a platform set on steel and wood piles, and a landing ship tank (LST) converted to a drilling tender, 10 miles off the Louisiana coast

1949	Seaboard Oil Co. & J.T. Hayward	Gulf of Mexico	*Breton Sound 20*: Submersible conventional-sized barge with pontoons on either side for stability and displacement control, up to 20' of water depth
1950s	Col. L.B. DeLong	100 miles off Cape Cod, MA	Invented the *Jack-up*: A platform with tall cylinders or caissons around the perimeter, that is floated to a site, drop the caissons to the bottom like legs, and then the platform is jacked up the remaining length of caissons as high above water as required
1950	Magnolia Petroleum Co.	Gulf of Mexico	Installed the first DeLong-design platform, *Jack-up*, stood on six caissons in 30 ft of water, as a permanent production platform
1951	McDermott Co.	Gulf of Mexico	*DeLong-McDermott No. 1*: Mobile *Jack-up* used for drilling

When	Who	Where	What
1953	*CUSS* group (*)	California Coast	*Submarex*: This former Navy patrol boat was converted into a drilling ship that drilled in water of 30-400 ft, but soon operations were limited to core sampling
1954	Bethlehem Steel Co.	Gulf of Mexico	*Mr. Gus*: A barge above a platform, and four legs that were slid down to the bottom, designed for 100 ft of water. It tilted and finally sank, ending the *"jack-down"* barge story
1954	Kerr-McGee Co. & Odeco	Gulf of Mexico	*Mr. Charlie*: Submersible barge rigged with pontoons at each of the long ends, ballasting one pontoon until the end of the barge sat on the bottom to ensure stability, and then filling the other. 20-40' of water depth
1956	Zapata Offshore Co. & R.G. LeTourneau	Gulf of Mexico	*Scorpio: Jack-up* with six 152-ft legs in two triangular sets with an 8-million-pound platform, where the lifting mechanism consisted on rack and pinion drives and electric motors
1961	*CUSS* group (*)	California Coast	*CUSS 1*: An US Navy barge is converted into this drilling vessel with no-self propulsion. It drilled in water up to 350 ft. Meanwhile, Socal and Brown & Root experimented with derricks on barges similar to the *CUSS* groups' ships
1961	Blue Water Drilling Co. and Shell's Bruce Collip	Gulf of Mexico	*Bluewater Rig No. 1*: The first large four-column semisubmersible built originally as a bottle-type and later Shell added additional ballast tanks to

			partially flood the four bottles. After this other semisubmersibles were built: Odeco's V-shaped platform *Ocean Driller*, or the triangular platform *Sedco 135*
1962	Kerr-McGee Co.	Gulf of Mexico	*Kerr-McGee Rig 54*: Last and largest submersible barge built that could drill in 175 ft of water. Submersibles barge designs varied until this barge was built, and all of them were used until the 1990s
1962	Sedco and Shell	Gulf of Mexico	*Eureka*: Drillship with port and starboard propellers extending from the bottom, that could rotate 360˚ to move the ship in any direction
1962	H.L Shatto and Shell	U.S. West Coast	*Mobot*: First remotely operated vehicle (ROV) used to operate an offshore well
1971	Sedco	Gulf of Mexico	*Sedco 445*: First dynamically positioned drillship built to drill exploratory wells in water depths up to 6,000 ft. It had fixed thruster, 11 along the port and starboard for lateral and heading control. The design became the standard for subsequent drillships

(*) *CUSS*: Consortium formed by Continental, Union, Shell, and Superior Oil Companies

Appendix 1. History of Offshore Technology for Oil/Gas Exploration and Production

Developments in the Gulf of Mexico (GOM) during the 1960-1970s and offshore Brazil in the 1970s initiated a huge step in the offshore and deepwater operations.

During the 1970s, the national petroleum company in Brazil, Petrobras, started exploring off the northeast coast of Brazil (with modest success) in their first discoveries in Campos Basin. Their goal was finding and producing hydrocarbon reserves to reduce their dependency on foreign production.

Fortunately, they were successful. Brazil has been a pioneer in developing technologies for deepwater operations in the petroleum industry, because they were stimulated by the successful discoveries in the 1980s in water depths up to 6300 ft (1920 m). Lessons learned in early production systems (EPS) and in designing floating drilling vessels and development systems, have provided good experience to the world petroleum industry to overcome the challenges found in deepwater fields.

Reserve discoveries during the 1980s in the GOM maintained the economic feasibility of offshore prospects despite the fluctuation in the oil prices. However, technical and economical limits for drilling vessels and production facilities were almost reached for prospects located on the Continental Shelf of the GOM. By the end of the 1980s, unsuccessful exploration operations and volatile oil and gas prices were the reason to consider exploring prospects (plays) in foreign offshore fields in Asia, Africa, Australia, and South America. The answers to the uncertainty in the GOM were fields in deeper waters and 3-D seismic to increase the reliability of plays.

The North Sea has been one of the most prolific regions for the offshore petroleum industry. The activity began in the early 1960s after the first gas well was discovered in 1959 off the Netherlands. By the mid 1970s, oil was discovered in the U.K. sector, but it was not until 1975 when the first oil production came ashore.

The North Sea produces hydrocarbons from five sectors administered by the Netherlands, Germany, Denmark, Norway, and the U.K. The region is characterized for rough weather conditions especially during the drilling process. Although there are economical benefits and the region is politically stable, North Sea production has been declining since the late 1990s. However, enhanced recovery techniques are planned to shore up production rates and bolster reserves.

Offshore technology basically initiated in the coasts of the U.S., but after the 1970s the technology has been constantly evolving due to requirements of the oil and gas industry and the current situation in the host countries of all continents. Currently, offshore developments are spread all over the word: The Gulf of Mexico, Brazil, West Africa, Australia, and the North Sea.

The hydrocarbon industry has been able to discover, reach and exploit oil and gas reserves in offshore fields through the support of:

- Many service companies, some of them from the nautical industry
- Publicly traded Oil Companies, such as Shell, ExxonMobil, ChevronTexaco, BP, ConocoPhillips, Kerr-McGee
- National Oil Companies such as Brazil’s Petrobras, Mexico’s Pemex, Nigerian National Petroleum Corporation, Norway’s StatoilHydro.

This work intends to show the current technologies, challenges, examples, and processes available for offshore exploration and production. During recent years more offshore fields in deepwater are being discovered and planned to be developed in the near future around the globe, in water of 10 000 ft (3050 m) and deeper. Therefore, many of the aspects described here will be applied, and many others will be created for the increasing oil and gas demand.

2. Offshore Development Systems

During the offshore exploratory phase, exploratory wells are drilled and completed to prove the presence of economic reserves. The success of these wells implies acquiring the information needed to justify the production of the field, such as 3D-4D seismic, produced fluid analysis, open or cased hole logging, core samples, pore and fracture pressure profile, adjusted mud weight, formation analysis, etc. All this information reduces the risk of drilling and completing future wells in the development phase.

After accomplished the phases described above, the multidisciplinary team responsible for the field has to make the decision on the best system for production and development. There are three categories for these systems: Fixed, Floating, and Subsea, see Figure 1.

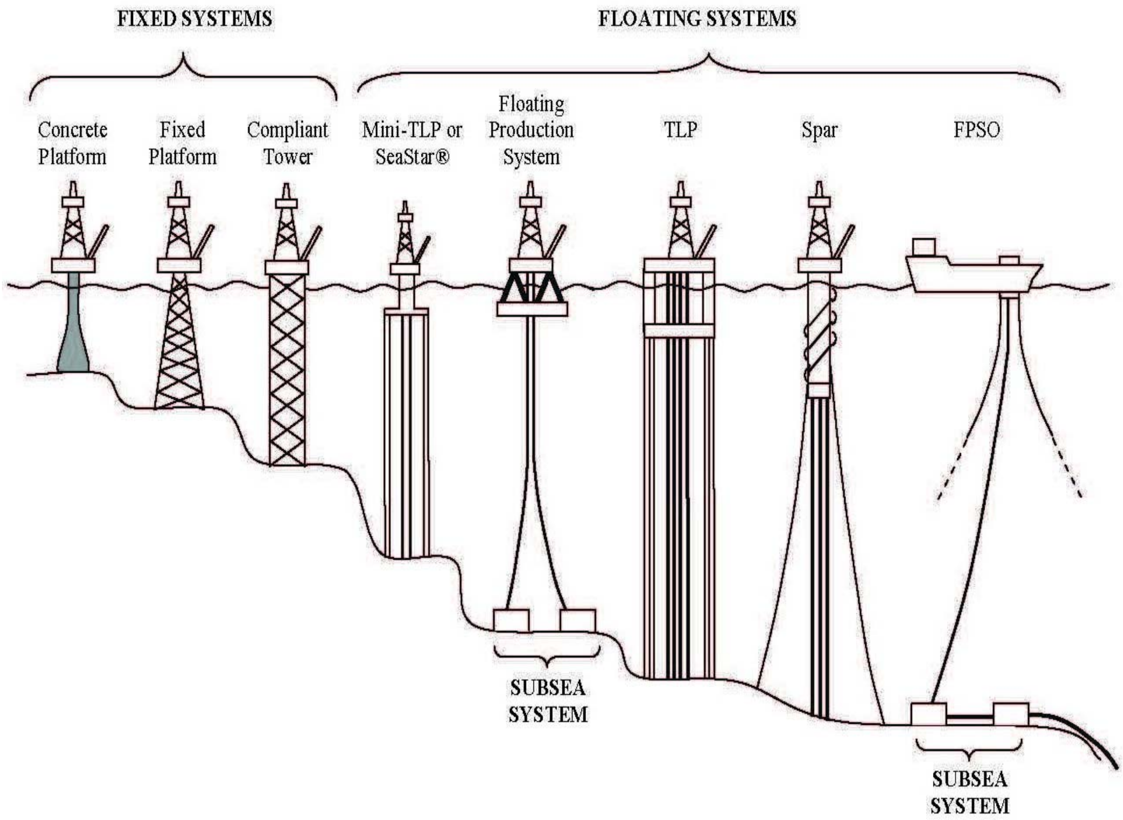

Figure 1. Offshore Development Systems

2.1. Fixed Systems

These are structures that sit on the seabed and are held in place by its own weight or by steel piles affixed to the structure. These systems include: fixed or conventional platforms, concrete or gravitational platforms, and compliant towers.

2.1.1. Fixed or Conventional Platforms

These have been used for offshore drilling and production for many years and are the conventional solution for shallow waters up to 1500 ft (457 m). The platform consists of:

- Tubular steel jacket, which is the vertical section from the seabed to above the water line
- Deck atop the jacket, where drilling and production equipment is located
- Steel cylindrical piles that secure the structure to the seabed

- Risers that are steel pipes that communicate the well from the seabed to the deck for drilling, completion, and production operations.

Example: Shell's Bullwinkle platform set in 1353 ft (412 m) of water in the Green Canyon area of the GOM is the largest of this type. (Mayfield et al.)

2.1.2. Concrete or Gravitational Platforms

These platforms are built from reinforced concrete, and as with the conventional platform, they are held in place by its own mass and sheer size. The maximum water depth for this type of structure is 1000 ft (305 m), and the seabed must withstand its heavy weight.

Example: StatoilHydro's Troll A platform in 994 ft (303 m) of water in the northern part of the North Sea.(www.statoil.com)

2.1.3. Compliant Towers

Similar to conventional platforms, they are tubular steel jacketed and bottom founded platforms that have the least footprint of the fixed systems. These are designed with a considerable amount of mass and buoyancy in the upper sections, so it's slender in shape. The design allows movement up to 10 to 15 ft (3 to 4.5 m) off center of the seafloor contact point.

The technical and commercial limit for this type of structure is 3000 ft (914 m) of water depth, where the conventional and the gravitational platforms are unfeasible. On the other hand, compliant towers do not work in water shallower than 1500 ft (457) because they would be too stiff to handle the waves and currents.

Example: Chevron's Petronius compliant tower in 1754 ft (534 m) of depth in the Viosca Knoll area of the GOM. (www.mms.gov)

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Biographical Sketches

Delgado, Johan has more than 11 years of experience in the petroleum industry focused in the drilling engineering discipline. He worked in the national petroleum company in Venezuela for 5 years as a drilling engineer in the West Division, including operational and engineering processes. He joined Halliburton in 2004 as a drilling consultant, starting working as part of multidisciplinary teams for the Mexican Petroleum Company, PEMEX, on planning and executing new wells, sidetracks, and completions in the Cantarell Field. He participated in the implementation of the Real Time solution for several wells.

He was transferred to the USA in 2007 as an in-house resource within the Chevron's Gulf of Mexico (GOM) Business Unit in New Orleans and Lafayette, Louisiana, where he gave support on the drilling and completion engineering process using the Landmark drilling products and the integrated environment with G&G information. Since 2008, he has been supporting Devon Energy on the drilling and completion engineering process to the drilling engineering staff in Houston and Oklahoma City using the Landmark products. Also, he has been applying collaborative well planning (CWP) and Real Time Monitoring workflows for drilling projects working in multidisciplinary teams. He got a BS in Electrical Engineering from Universidad del Zulia, Venezuela in 1997, and a MEng in Petroleum Engineering from Texas A&M University in 2008.

Jerome J. Schubert is an Assistant Professor in the Harold Vance Department of Petroleum Engineering at Texas A&M University. Dr. Schubert has earned B.S., M.Eng., and Ph.D. degrees in Petroleum Engineering Texas A&M University. Dr. Schubert has over 30 years in the petroleum industry with Pennzoil Company, Enron Oil and Gas, the University of Houston-Victoria Petroleum Training institute and Texas A&M University. He joined Texas A&M as a Lecturer in Petroleum Engineering in 1994 and was promoted to Assistant Professor in 2004. Dr. Schubert's main research areas include Deepwater Drilling, Managed Pressure Drilling and Well Control. Dr. Schubert is a co-author of the textbook, Managed Pressure Drilling, and an author of more than 35 technical papers. He has been a committee member for several Society of Petroleum Engineers (SPE) and International Association of Drilling Contractors (IADC) conferences and events, and a technical editor for "SPE Drilling and Completions". He serves as Faculty Advisor for the Pi Epsilon Tau and the American Association of Drilling Engineers student section.

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He has published more than 80 technical papers, from which more than 12 are peer-reviewed.