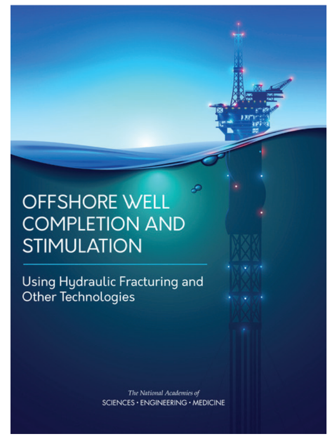
Offshore Well Completion and Stimulation: Using Hydraulic Fracturing and Other Technologies

PROCEEDINGS OF A WORKSHOP



The National Academies' Roundtable on Unconventional Hydrocarbon Development held a workshop to increase public understanding of offshore well completion and stimulation technologies, including gravel packs, "frac-packs," and acid stimulation. The workshop examined the unique features of U.S. offshore oil and gas activities, focusing on the Gulf of Mexico—including operational technologies, environmental considerations and concerns, and health and safety management. Participants from across government, industry, academia, and nonprofit sectors shared their perspectives on operational and regulatory approaches in the development of offshore resources.

Offshore activities on the U.S. Outer Continental Shelf (OCS) represent a significant portion of federally derived oil and gas production—generating $30 billion to the U.S. economy and sustaining approximately 315,000 jobs during fiscal year 2016. Offshore production in the U.S. OCS occurs in three main regions: the Gulf of Mexico, offshore California, and offshore Alaska, with the majority of production occurring in the Gulf.

The life cycle of an offshore oil and gas field extends over several decades and includes five general stages: exploration, drilling, completion, production, and decommissioning. Exploration for economically recoverable hydrocarbon reservoirs takes place over roughly five to ten years. Where potential oil or gas accumulations are identified, exploratory drilling is carried out to confirm the producibility and economic potential of the hydrocarbons. If economically recoverable accumulations are identified, the well is then 'completed', or prepared for production. Production itself may last 15 to 30 years. When a well is no longer yielding economically viable quantities of hydrocarbons, the well is reclaimed or plugged in a process called decommissioning.

OFFSHORE TECHNOLOGIES IN PRACTICE

Unique challenges in offshore environments require advanced engineering technologies and approaches to produce oil and gas from wells. These technologies, protocols, and regulations are directed toward delivering oil and gas in quantities needed to make wells economically sustainable and to ensure production that is safe both for well workers and the environment. Well completion activities are particularly crucial in this regard and several types of well completion and stimulation approaches are available to address the requirements of individual wells (see Box 1).

The selection of completion technology or approach depends upon reservoir characteristics specific to that well. Some of the key characteristics include the type of rock formations being drilled and the porosity, permeability, pressure, and temperature of the zones from which oil or gas are going to be produced. In the Gulf of Mexico, for example, a central objective in all operations is sand control and control of any associated

BOX 1
COMPLETION AND STIMULATION DEFINITIONS

Gravel Pack: A sand-control method used to prevent production of formation sand. A steel screen is placed in the wellbore and the space around the pipe in the wellbore is packed with prepared gravel of a specific size.

Frac Pack: A sand-control method that combines the production improvement from hydraulic fracturing with the sand control provided by gravel packing. The process involves simultaneous hydraulic fracturing of a reservoir and the placement of a gravel pack to connect the reservoir fluids to the wellbore and allow fluids to flow at lower pressures.

Acid Stimulation: Pumping a stimulation fluid containing a reactive acid into a reservoir in order to improve permeability and productivity of a well.

Hydraulic Fracturing: A controlled, high-pressure injection of fluid and proppant into a well to generate fractures in the rock formation to stimulate production of oil and gas. Proppant includes sand or ceramics that help keep hydraulic fractures open after fluid injection is completed. While common in development of tight onshore oil or gas fields in the United States, hydraulic fracturing is not used often in offshore settings and is conducted at a smaller scale relative to hydraulic fracturing activities onshore that also involve horizontal drilling.

erosion within the well due to the types of rock formations from which hydrocarbons are typically produced. On balance, the engineering techniques used to complete offshore wells have existed for several decades with no dramatic changes in the primary approaches used.

Completion and Stimulation in the Gulf of Mexico

The type of rock through which a well is drilled to produce offshore oil or gas in the Gulf of Mexico falls generally into two broad categories: unconsolidated sands which are shallower and usually between three and 23 million years old and consolidated sands which are deeper and geologically older, typically between 23 and 66 million years old. Two approaches are generally used for sand control of unconsolidated sands—the gravel pack and the frac pack. Gravel packs are used in less than ten percent of completions in the Gulf while frac packs are used for 75 percent of well completions.

For consolidated sands, fracture stimulations (i.e., hydraulic fracturing) may be performed to aid production of oil and gas from wells. Hydraulic fracturing can minimize the number of wells needed to develop a reservoir, thus having less impact on the marine environment. However, the high cost of this approach can be prohibitive in the offshore environment and is used in less than ten percent of completions in the Gulf. High-volume hydraulic fracturing together with horizontal drilling of unconventional formations such as those used for shales and tight sandstones onshore in the United States does not take place offshore.

Other types of well stimulations may be used to increase the rate of oil flow to the well from an offshore reservoir when natural flow characteristics are not favorable for either unconsolidated or consolidated rock formations. Proppants, additives, water, and other substances may be blended and pumped into the wellbore to increase productivity. In unconsolidated sands in the offshore conventional environment, less than 5,000 barrels of proppant (210,000 gallons) may be needed. In consolidated sands, more than 5,000 barrels may be needed at each stage of the completion with 2 to 5 stages likely. By comparison, well stimulations onshore may require in excess of 30,000 barrels (1.26 million gallons) per stage with more than 10 stages possible.

BOX 2
ON THE STIM STAR IV

Aboard the Stim Star IV, a stimulation vessel, approximately 3 million pounds of proppant and 40,000 barrels of fluid are stored for a typical consolidated frac pack.

In the Gulf of Mexico, deepwater drilling activities rely on saltwater instead of hauling water from onshore. Ninety-five percent of stimulation fluid is composed of seawater or brine.

In well stimulations, chemical additives are injected in order to reduce friction in the pipe and help carry the proppant into the fractures. The additives are non-priority pollutants subject to static sheen and oil and grease testing from the industry.

Specially equipped stimulation vessels are used to provide the necessary equipment and execute the processes to complete wells in the offshore. These vessels (see Box 2) carry all necessary supplies for drilling, completions, and stimulations including storage for proppants, fluids, pressure pumps, and the hoses that supply fluid from the vessel to the drill ship. The five stimulation vessels in operation in the Gulf are placed in close proximity to the drill ship through the use of dynamic positioning which ensures the vessel stays in a specific, safe location.

SAFETY AND ENVIRONMENTAL CONSIDERATIONS

Offshore oil and gas exploration and production are regulated to address both the operational and environmental aspects of these activities. Federal regulations from the Occupational Safety and Health Administration, the U.S. Coast Guard, and the Bureau of Safety and Environmental Enforcement serve to protect workers.

Information shared at the workshop suggested an overall decrease in the loss time incident rate between 1968 and 2007, despite a 10-fold increase in work hours. Ensuring personnel safety and avoidance of major incidents requires a dual approach—one involving rule- and inspection-based systems and one that is performance-based. As the approach to an offshore safety culture has become more normalized, any person working in the offshore environment is anticipated to be able to respond to the following kinds of questions: What are the major hazards? What are the barriers for limiting these hazards, and are they effective? What is your personal responsibility for those barriers?

Additional federal and state governmental regulations, permits, and industry standards exist to improve worker and environmental safety and public health. Water and waste discharges, for example, are regulated and permitted by the U.S. Environmental Protection Agency, U.S. Department of Transportation, and individual states. These permits contain specific testing requirements and limits for discharges from completion, treatment, or byproducts and are renewed every five years. Completion or stimulation fluids that fail to meet standards are shipped to shore for disposal, reuse, or recycling under state regulations. The Bureau of Ocean Energy Management (BOEM) regulates energy resources. BOEM uses the Outer Continental Shelf Lands Act's environmental standards, the National Environmental Policy Act, and other statutes and directives as a guide to informed decision making which includes analysis of authorized activities, evaluation of alternative approaches, and creation of scientifically motivated mitigation strategies.

Environmental concerns from offshore activities include oil spills, seafloor-bottom disturbance, noise, vessel traffic, air emissions, and lighting. Data have been collected on a range of environmental programs including effects of seafloor discharges, methods development for toxicity testing, laboratory studies on toxicity and bioaccumulation, containment studies, baseline studies, and acoustic effects on the marine environment. Since the Deepwater Horizon oil spill, an influx of information has also emerged from studies on the ecology of the Gulf of Mexico.

APPROACHES IN THE OFFSHORE PACIFIC

Rock formations are the main difference between offshore activities in the Gulf of Mexico and in the Pacific Ocean, offshore California. In the Gulf, while sand control is the primary focus of well completion, in the Pacific, the reservoir rocks are consolidated and contain significant natural fractures, which can cause reservoir damage when drilling. Well stimulations and mitigating reservoir damage are a major focus of the well completions.

The majority of well stimulation activities in the offshore Pacific involve matrix acid. Offshore acid treatment volumes are drastically less than unconventional fracture treatments onshore. In the offshore environment, 600 to 6,000 gallons of acid may be required, while onshore volumes range between 30,000 and 50,000 gallons. Acid treatments treat the entire well which adds challenges to the completion.

In California, laws for well stimulation activities, including hydraulic fracturing, were created to manage hazards and risks to the environment and public health in the onshore and offshore. The laws require, for example, a study of well stimulation, a statewide environmental impact report, and the development of well stimulation regulations for the onshore and the offshore.

PLANNING COMMITTEE FOR THE WORKSHOP ON OFFSHORE WELL COMPLETION AND STIMULATION: USING HYDRAULIC FRACTURING AND OTHER TECHNOLOGIES

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ABOUT THE ROUNDTABLE ON UNCONVENTIONAL HYDROCARBON DEVELOPMENT

Launched in 2015, the Roundtable provides a neutral forum where representatives from government, industry, academies, and nongovernmental and international organizations can critically examine the facts about the scientific, engineering, health and safety, regulatory, economic, and societal aspects of unconventional hydrocarbon development.

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