Burnett Ranch: A CO\(_2\) Flood on the Eastern Shelf of the Permian Basin, King County, Texas*

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Search and Discovery Article #11234 (2019)**
Posted July 15, 2019

*Adapted from poster presentation given at 2019 AAPG Southwest Section Meeting, Dallas, TX, United States, April 6-9, 2019
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Abstract

The Burnett Ranch Field, located in King County, lies on the Eastern Shelf of the Permian Basin. Consisting of multiple—and in certain areas, stacked—reservoirs and multiple fields, the Burnett Ranch boasts a long and storied history, both with regards to its geology and petroleum system. The primary reservoirs in this area are Pennsylvanian-aged Strawn sandstones, with secondary Strawn limestones, Permian-aged Tannehill sandstones, Pennsylvanian-aged Bend conglomerates, Mississippian-aged Marble Falls-equivalent limestones, and the Ordovician-aged Ellenburger carbonates. The first marginally successful well was drilled in the field in the 1950s, but it was not until the 1970s when primary production sharply increased with the discovery of the major oil fields in the area. The Burnett Ranch changed operators multiple times thereafter, and secondary production efforts began in the 1980s. Hunt acquired the acreage in the early 1990s and initiated tertiary production in the 2010s, which continues to this day. The primary reservoirs in the field are the Twin Peaks Sands, the Strawn Lower Sand, the Strawn 5400’ Sand, and the Strawn 5400’ Lime. All four of these reservoir intervals are alternately flooded with both CO\(_2\) and water based on individual well production. There are currently 36 injectors and 46 producers, around which injection-centered patterns are drawn. The traditional five-spot injection pattern is not used in the field due to the considerations of topography, the use of existing wellbores, and the need to optimize locations with stacked reservoirs. The CO\(_2\) flood is currently progressing from the northern end of the field to the south. Injectors on the outskirts of the CO\(_2\) flood are used to create higher pressure in the downdip reservoir to keep the CO\(_2\) inside the hydrocarbon-bearing portion of the reservoir. Once injected into the reservoir, CO\(_2\) at certain temperatures and pressures will become miscible with the residual oil left behind after primary and secondary production. The resulting mixture of oil and CO\(_2\) has a reduced viscosity, which allows it to flow more easily through the reservoir. The purpose of alternating CO\(_2\) injection with water is to force the CO\(_2\) down new pathways through the reservoir—the water fills the CO\(_2\)-created pathways and block them off from any CO\(_2\) injected thereafter. This is the mechanism by which the life cycle of a field that otherwise would have been abandoned is extended, allowing it to produce an additional 10-15% OOIP.
CO₂ floods operate through the combined use of injection and production wells. CO₂ is injected into the reservoir as a supercritical fluid. The CO₂ becomes miscible with the residual oil, and the resultant mixture is less viscous and therefore easier to mobilize. The injection of CO₂ is alternated with the injection of water—this method of enhanced recovery is known as water alternating gas, or WAG. Water is periodically injected into the reservoir after CO₂ to create new channels for the CO₂ to disperse through: the water follows the pathways through the reservoir created by the CO₂ and essentially blocks that pathway, thereby forcing the CO₂ injected after the water to create new pathways through the reservoir. Water curtain wells around the periphery of the reservoir help to contain the CO₂. Through this method, incremental recoveries of 10–20% OOIP may be achieved.

Regional Petroleum Systems
King County lies on the western edge of the Fort Worth Basin and the eastern edge of the Permian Basin. The source rock for Burnett Ranch is not in the immediate area, as wells drilled to the basement did not penetrate shales of both notable thickness and high total organic content. Several source possibilities for Burnett Ranch exist: the Pennsylvania Smithwick Shale and Bend Group mudstones, Mississippian Barnett Shale, or the Upper Devonian Woodford Shale. As none of these shales exist with considerable quantity within the Hunt Burnett Ranch, extensive migration from either basin is assumed.

Strategic and Depositional Environment
Multiple reservoirs within multiple fields make up the Hunt Burnett Ranch. The main reservoirs in Burnett Ranch are Pennsylvanian Strawn sandstones and limestones. The primary reservoir intervals consist of the Strawn 5400 Sandstone and Strawn Lower Sandstone, and Strawn 5400 Limestone. Secondary reservoirs include the Twin Peaks Sandstones, along with the Tarrant Sandstones, Strawn reefs and carbonates, Bend Conglomerates, and Mississippian carbonates.

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Historical Production
Shell first drilled several wells in the area in the 1950s. The well was marginally successful and the property changed hands several times afterwards. Gunn was responsible for the discovery of the major oil fields in the area and the start of a noticeable increase in primary production in the early 1970s. Secondary production in the form of waterflooding the reservoirs began in the mid 1980s. Hunt acquired the acreage in the early 1990s and initiated tertiary production in the mid 2010s, and the injection of CO₂ into the Burnett Ranch reservoirs continues to this day.

How CO₂ Floods Work
CO₂ floods pose a number of challenges. Points to consider include:
- Corrosion – The presence of carbonic acid translates to the need for specialized coatings and materials for any and all equipment that comes into contact with fluid produced from the reservoir.
- Fluid chemistry – The addition of CO₂ in the reservoir affects the chemistry of the fluids within the reservoir and can potentially change the precipitation threshold for certain compounds such as asphaltenes.
- Processing speed – The time it takes for the reservoir to process the amount of time it takes for injected CO₂ to show up in a nearby producer and is dictated by injection rate, injection pressure, and properties of the reservoir.
- Conformance – The uniformity of the flood front sweep, poor conformance in both the vertical and lateral directions is indicative of variabilities in permeability, which may lead to inefficient flooding.

The Hunt Burnett Ranch at Present
Burnett Ranch operates as a successful CO₂ flood. The flood consists of 70 wells total: 38 producers, 26 CO₂ injectors, and 6 water injectors which are split into 26 injector-centered patterns that cover the reservoir intervals earmarked for CO₂ flooding. CO₂ injection began in the northeast and progressed to the southwest. Water injectors outside the bounds of the flood help contain the CO₂ to the productive area. Up to four reservoir intervals may be simultaneously flooded by an injector, and the processing speed for each reservoir differs both laterally and vertically. To date, good response has been seen so far with peak tertiary production rates—which on average, have been 14x higher than pre-response rates. Continued development and expansion to the far southwest of the field have been planned for 2020.