AIR INJECTION FOR CALIFORNIA MATURE OILFIELD

BOTTOM LINE

The State of California has an estimated 3.5 billion barrels of oil reserves. 76% of those reserves are heavy oil (API gravity 10 to 20). These deposits were discovered early, between 1880 and 1920, and a wide range of techniques, thermal and non-thermal, have been applied to producing this large resource, yet between 61 and 69% of the original oil remains in place. One thermal technology, Air Injection (also called in-situ combustion and fireflood) held promise in the 1960s and 1970s but did not live up to expectations. Can it be revived using today's technological advances?

PROBLEM ADDRESSED

In theory, Air Injection should recover a high percentage of remaining oil in place in the mature heavy oil fields in California, through the mechanisms of viscosity reduction, increased pressure gradient and upgraded crude quality. However, corrosion, emulsion, and inability to control the flame front led to poor results in the 1970s. Drilling and monitoring technology have improved considerably since then. It may be time to take a second look.

KEY WORDS:

- Air Injection
- Cyclic Steam Stimulation
- Double Displacement Process
- Fireflood
- Heavy Oil
- In-Situ Combustion
- Steam-Assisted Gravity Drainage
- Steam Flood

TECHNOLOGY OVERVIEW

Examples of In-Situ Combustion Projects

In the 1960s and 1970s approximately 40 air injection full field or pilot projects were undertaken throughout the world, mostly in the U.S. and mostly directed at recovering heavy oil. Several of the longer term, full field projects were in the heavy oil fields of California, in the San Joaquin Valley. The largest was the West Newport field, which at one time was producing 3,000 barrels/day from 100 producers. Others included the Lost Hills, producing 800 b/d from 40 producers and Midway Sunset - Potter at 1,200 b/d. While some of the projects were clearly successful, recovering up to 50% of the original oil in place, overall the results did not live up to expectations.

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SPEAKERS:

Examples of In-Situ Combustion Projects
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In-Situ Combustion in California - Re-Igniting the Spark
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Concepts of the Double Displacement Process Using Air Injection
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Heavy Oil Resources in California
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San Joaquin Valley Air Pollution Control District (SJVAPCD) Permitting Requirements for Oil Production Operations
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The mechanisms that make a successful project are the reduction in the viscosity of the oil, building up a pressure gradient, and upgrading the crude by burning the heavier hydrocarbons. The controlling factors include the oil saturation and gravity and reservoir porosity, permeability, heterogeneity and dip. The problems that occurred that caused less than optimal recovery included the rusting and plugging of injectors with asphaltene, emulsions, subsurface scale, corrosion and gas buildup at producers, the failure to ignite or control the flame front, and gravity segregation.

In-Situ Combustion in California—Re-Igniting the Spark

Many lessons about producing heavy oil may be learned from Canada, which has an estimated 2.5 - 3 trillion barrels of heavy oil and bitumen deposits, 175 billion barrels of which is proved. Most of these deposits are in Alberta, which produces 550 Mb/d from mining and 450 Mb/d by in-situ methods. A number of in-situ thermal and non-thermal technologies have been brought to bear on this resource. Non-thermal technologies include primary production, cold production with sand, cyclic gas injection, waterflooding, water-alternating-gas (WAG), solvent vapor extraction and combinations of those methods.

Most of the heavy oil is produced through steam-based technologies. These include steam flood, cyclic steam stimulation (CSS), steam-assisted gravity drainage (SAGD), steam and gas combined, and steam and solvent combined. The largest of these is the CSS driven Cold Lake field at 150 Mb/d. There are over 20 SAGD projects ongoing, where steam is injected in a horizontal well in the upper part of the formation and produced from a horizontal well in the lower section. This technique requires that the formation be at least 75 ft. thick and continuous, with no vertical permeability barriers. There are issues with steam technologies. It is not universally applicable, the cost and environmental effects of the fuel, and need for water sourcing and treating.

Given the resource base and the issues with steam, air injection, with and without accompanying water injection, is being re-examined as an option. At one time, there were 16 air injection projects in Alberta and Saskatchewan modeled after the California floods. But like California, there were more failures than successes. Like California there were problems with sand production, corrosion, gas locking and difficult emulsions. So why reconsider air injection? Besides the size of the resource and issues with steam, today there are better production procedures and equipment, better access to the reservoir with horizontal wells, and better understanding of the process mechanisms, particularly the oxidation kinetics and relative permeability effects of liquid-blocking gas flow.

Based on the improved understanding the following operating strategies are recommended: (1) need to ensure operation is in the high temperature range with high temperature ignition and air injection rate to match the pattern size, (2) account for the fluid-blocking behavior with some initial depletion, enhanced mobility paths, and plan for some pressure increase at ignition, and (3) consider water co-injection. Based on those strategies, screening criteria for air injection include:

- Oil must have sufficient mobility at reservoir temperature to be captured by producers;
- Sufficient gas injectivity must exist to maintain oxygen flux above minimum level for maintaining the desired combustion mode;
- Oil volume at the start of the process must be sufficient to justify installing capital equipment;
- Reservoir must be sufficiently deep and confined to prevent breakout of air; and
- Oil should show stable burning characteristics in a laboratory setting

Concepts of the Double Displacement Process Using Air Injection

The double displacement process (DDP) has long been used on dipping structural reservoirs with an active aquifer. With the producer completed just above the original oil/water contact the well would water out as oil was withdrawn and water swept through. By injecting gas at the crest, it would force the oil down to the producer through gravity drainage and maintain the oil/water contact. An extension of DDP is the second contact water displacement with the producer on the crest, over residual oil, oil bank and second water contact with the aquifer. The residual oil saturation is dependent on the capillary number. The DDP is very efficient, recovering 85 - 95% of the original oil in place, compared to 60 - 78% with the aquifer alone. At West Hackberry field in Louisiana, air injection versus natural gas has proven to approach the same high recovery factor.

Heavy Oil Resources in California

Much of the lower 48 states' heavy oil is in California, mostly in the San Joaquin Valley and along the southern and central coasts. Much of it is concentrated in Kern County, which produced 126 million barrels in 2004. Oil is considered "heavy" if it has API gravity from 10 to 20, or viscosity from 100 to 10,000 centipoises at original reservoir temperature. 76 percent of California's 3.5 billion barrels of proven reserves are classified as heavy. The deposits are very mature, having been discovered early in the 20th century and many are quite large. Midway-Sunset produced 44 million barrels in 2004, Kern River 35 million, South Belridge 16 million and Cymric 19 million barrels.

The earliest production was developed around seeps over the shallow reservoirs. Wells were drilled to increase production, as were simple pits and oil tunnels. Still after decades, only a few percent of the original oil in place had been recovered. Operators began using steam in the early 1960s to reduce the viscosity by a factor of up to 1,000, dramatically increasing production. Both cyclic and steamfloods were developed. The steamfloods were more efficient than the cyclic steam, but more costly and uneconomic below 3,000 - 4,000 feet. Production of heavy oil in California was 100 million barrels in 1960 and peaked at 250 million barrels in 1985. It is estimated that 61 - 69 percent of the original oil is still in place.

San Joaquin Valley Air Pollution Control District (SJVAPCD) Permitting Requirements for Oil Production Operations

Despite years of improvements, the San Joaquin Valley air basin violates federal and state ambient air quality standards. Ozone, caused by VOCs and NOx from vehicle emissions, factories, paint and livestock is a summer problem. Particulate matter - smoke, ash, dust, diesel exhaust and chemicals is a fall and winter problem.

Besides the normal drilling permits, much of the normal production equipment will require a permit, including steam generators, heater treaters, thermally enhanced wells, storage tanks and any internal combustion engine over 50 horsepower (Rule2010). Further, rule 2201 requires best available control technology (BACT) on new emission units. Offset may be required at certain emission levels of NOx, VOC, particulates, SOx, and CO. Further, Regulation IV is intended to reduce emissions from existing equipment. It is not as stringent as BACT, however. Regarding requirements for crude oil wells enhanced by air or inert gas injection, an authority to construct permit is required for all wells at a specified location or all wells served by a common vapor control system.

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